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## THE NEWARK SYSTEM OF NEW JERSEY.[1]

THE Newark system extends across the northern part of New Jersey, forming a belt which is about thirty-two miles wide along the Delaware River, while its width at the New York state line is about fifteen miles. The southeastern boundary from Trenton northeastward to Staten Island is for the most part formed by the overlying Cretaceous beds. Near Trenton, however, the underlying Philadelphia gneiss outcrops for a few miles. The waters of the Kill von Kull, New York Bay and Hudson River form the boundary from Staten Island northward. The northwestern boundary is irregular and is formed entirely by older rocks, — crystallines and Palæozoic shales and limestones. This paper has to do with that part of the area lying southwest of a line drawn from Metuchen, through Plainfield to Peapack.

*Topography.*—In general the area is a gently rolling plain, having an average elevation of 100 to 250 feet A. T. The plain is interrupted by the valleys and trenches of the present streams and hills, ridges and plateaus of harder rock. The largest of these is the Hunterdon plateau. Commencing at Raven Rock on the Delaware River a prominent escarpment extends northeastward, past Flemington, where it bends north and then northwest, finally terminating near Lansdown about eighteen miles from the

[1] Published by permission of the State Geologist of New Jersey. For a more detailed statement of all the facts upon which this paper is based, see Annual Report of the State Geologist for 1896, pp. 25–88.

Delaware River. Northwest of this line is a broad plateau, having an average elevation of about 600 feet. It extends westward into Pennsylvania, being dissected by the Delaware to a depth of 400 to 500 feet. Its highest part is along the south and east, about a mile back from the top of the escarpment. Thence it declines in elevation very gently northward and westward. The escarpment is most marked in the vicinity of Flemington, where the contrast in hardness between the rocks of the plateau and of the low ground is the most marked.

Sourland plateau extends from Lambertville on the Delaware, northeastward for seventeen miles. It has an average width of four and a half miles and varies in height from 450 to 560 feet. The backbone of the plateau is a belt of trap rock, a mile in width, but the hard sandstones and argillites on either side rise nearly to the same elevation. In the vicinity of Hopewell and northward, the plateau is separated from the low plain to the southeast by an escarpment varying from 200 to 400 feet in height. Other masses of trap rock forming minor hills and ridges rise from 200 to 500 or 600 feet above the general level. Along the northwestern boundary also there are several marked elevations due to massive quartzite conglomerates.

## THE ROCKS.

It has been found possible to divide the sedimentary rocks of the Newark system into three subdivisions.[1] These are not based upon palæontological evidence, since fossils are too few to be used for this purpose, but on lithological differences, which permit the establishment of recognizable horizons. While fully aware of the dangers attending the use of lithological characters in correlation, the author is confident that in this case they have been reduced to a minimum, owing to the care with which the beds have been traced step by step. The beds of the three series

[1] Practically all the outcrops and sections — many hundreds in number — have been examined and plotted. All the roads and nearly all the stream beds have been traversed. So monotonous are the beds that it is only by this detailed work that there is any possibility of detecting and tracing the structural complications.

grade into each other vertically through transition zones several hundred feet in thickness, so that it is not always easy to delimit them exactly in the field. Moreover, all three members lose to a great extent their distinctive characteristics when traced along the strike of the northwestern boundary north of Pittstown. With these exceptions, however, the beds of each division are *en masse* quite unlike and readily separable from each other. The accompanying map shows their location and the main faults by which they are repeated.

*Stockton series.*—The basal beds of the system are found at Trenton where they rest unconformably upon the older crystalline rocks. They consist of (*a*) coarse, more or less disintegrated arkose conglomerates; (*b*) yellow, micaceous, feldspathic sandstone; (*c*) brown-red sandstones or freestones, and (*d*) soft red argillaceous shales. These are interbedded and many times repeated, a fact which indicates rapidly changing and recurrent conditions of sedimentation. Although there are many layers of red shale in this subdivision the characteristic beds are the arkose conglomerates and sandstones, the latter of which afford valuable building stones.

In addition to the cross-bedded structure which often prevails in the sandstones, ripple-marks, mud-cracks and impressions of rain drops occur. The rapid alternation from conglomerates to shales and *vice versa*, the changes in composition in individual beds, the cross-bedding, ripple-marks, etc., all indicate very clearly that these beds were deposited in shallow water in close proximity to the shore. The bulk of the material of which they are composed was derived from the crystalline rocks on the south and southwest.

Owing to the tilting and faulting, the Stockton beds outcrop in several belts as shown by the map. The most important areas are (*a*) the Trenton area, which extends northeastward to Princeton beyond which place it is mostly buried by Cretaceous and Jamesburg deposits; (*b*) the Hopewell area along the southeastern face of the Sourland plateau, where the upper part of the series has been brought to the surface by a fault; (*c*) the

Stockton area, where the upper layers are exposed in numerous quarries near the village of Stockton; (*d*) the area north of Flemington.

In the Stockton area the upper limit of the series extends along the crest of the escarpment of the Hunterdon plateau, the steep slope being formed by the upper beds of Stockton series which are here predominantly red shales, with an occasional sandy layer. Northeastward this belt is terminated by a great fault which crosses the beds obliquely so that the belt becomes narrower and finally pinches out a few miles southwest of Flemington. Within this area the more massive conglomeratic beds form three broad low ridges, each of which terminates somewhat abruptly at the fault.

An important modification was found in the character of this series within the area north of Flemington. Where the rocks first occur near Flemington, they consist of coarse arkose sandstones and red shales. The transition here to the overlying series is through sandy shales similar in texture and thickness to the uppermost layers northwest of Stockton. As the northwestern border of the formation is approached the arkose conglomerate and sandstones give place to red shale beds or sandstones and conglomerates of a different type. For a distance of four miles southeast of Clinton the basal beds of the formation rest unconformably upon Silurian shales, limestones, and still older quartzite and gneiss. Material from these formations has determined the local character of the Newark beds. In place of the free-splitting brown and red sandstones, there occur coarser beds made up largely of thin bits of shale, and small quartzite pebbles. Although the Stockton beds rest in part upon the limestone and gneiss, these rocks occur but rarely in this part of the newer formation. Their comparative absence has not been satisfactorily explained.

*Lockatong series.*—Above the Stockton beds there is a series of hard, dark-colored shales and flagstones, which I have called the Lockatong beds from the name of the creek in Hunterdon county, along which they are best exposed. They consist of

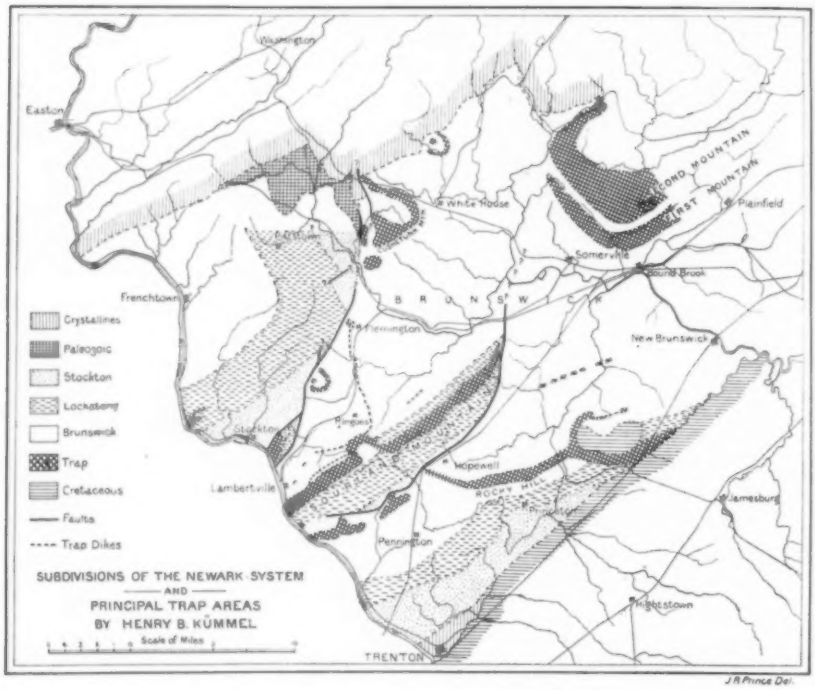
(*a*) carbonaceous shales, which split readily along the bedding planes into thin laminæ, but have no true slaty cleavage; (*b*) hard, massive, black and bluish-purple argillites; (*c*) dark gray and green flagstones; (*d*) dark red shales approaching a flagstone; (*e*) and occasional thin layers of highly calcareous shales. There are all gradations between these somewhat distinct types, so that the varieties of individual beds are almost countless. Some of the argillites are specked with minute crystals of calcite and the faces of joint planes and cavities are frequently covered with deposits of the same mineral. Minute crystals of iron pyrites occur frequently in some layers, but apart from them and the calcite, secondary minerals were not found, macroscopically, in these beds.

Both ripple-marks and mud-cracks occur at all horizons in the Lockatong beds, showing that shallow water conditions prevailed throughout the time of their deposition. On the other hand, the absence of strong currents or violent shore action is indicated by the extreme fineness of the material.

Owing to the faulting these beds occur in several well-marked belts, in each case overlying conformably the Stockton series. The first belt reaches the Delaware between Wilburtha and Washington's Crossing, and extends northeastward through Ewingville, Lawrenceville, and Princeton, where there are several large quarries in the argillite beds. East of the Millstone River the limits of this belt cannot be determined accurately owing to the veneer of the Jamesburg formation, but from a few scattered outcrops and borings, these beds probably cross the Raritan River below the mouth of Lawrence Brook.

The Lockatong beds occur again along the southeastern side of the Sourland plateau, resting upon the narrow belt of Stockton sandstones which forms the escarpment of this upland. From the Delaware River to the village of Newmarket the upper limit of the beds lies a little below the trap sheet which forms the backbone of the upland. The interval between them is occupied by the softer red shales of the third series, which are somewhat metamorphosed near the igneous rock. Northeast of New-

market, owing to a sharp curve in the trap sheet by which it crosses the beds nearly at right angles, the Lockatong beds occur on both sides of the trap, their upper limit being about 1760




feet above the latter. The plateau, which owes its elevation to the hardness and durability of the argillite flagstones and trap, is terminated on the northeast by the fault.

The most extended outcrop of the Lockatong beds occurs on the Hunterdon plateau, in the region known as "the Swamp." As shown on the accompanying map the width of the outcrop is greater here than elsewhere due to diminished dips, 10° to 13° here as against 15° to 20° on the Sourland plateau, and the belt

forms a broad regular curve, due to the synclinal structure. The height of the Hunterdon plateau is due to the wide outcrop, curving strike and hardness of these rocks and of the upper layers of the Stockton series, all of which have retarded greatly the forces of denudation, so that whereas the adjoining softer rocks have been reduced to an average elevation of under 200 feet, this belt has an elevation of from 500 to 700 feet.

Along the Lockatong and Wickecheoke creeks, which have deeply incised the margin of the plateau, rapids and falls abound. Hard dark red flags are interbedded with the black argillites, and some of the more pronounced beds can be easily traced for several miles along the curving strike. This was done in so many cases at different horizons as to render it almost certain that this belt is not traversed by faults of any magnitude. The width of outcrop is due to the great thickness and the gentle dip.

*Modification of the Lockatong beds.*—Important modifications were found to occur in this series near the northwestern boundary. The shales and argillites grade into sandstones, and these into coarse conglomerates. Some layers become slightly arkose. This change occurs *along the strike*, and is accomplished within six miles or less. Within a mile and one-half along the strike from the point where the first pebble-bearing layers were noted, the series is composed chiefly of massive conglomerates in which the pebbles are frequently six or eight inches in diameter. Since not only the Lockatong beds but the next higher series also grade into these marginal conglomerates, it will be well to postpone further consideration of them for a brief space.

The Lockatong beds give rise to a rather heavy wet clay soil. The surface is quite thickly strewn with slabs of argillite and flagstone, and on the slopes outcrops are generally abundant. Except in places favorable to the accumulation of the soil from higher slopes its depth is generally less than five or six feet.

*The Brunswick shale series.*—I have applied this name to the great thickness of soft shales and occasional sandstone layers

which overlie the Lockatong beds, and which are so well exposed in the valley of Raritan, particularly near New Brunswick. They are predominantly red in color, although a few purple, green, yellow, and black layers occur. In general this series consists of a monotonous succession of very soft argillaceous red shales which crumble readily to minute fragments, or split into thin flakes. Much of it is porous, the minute, irregular-shaped cavities being often partially filled with a calcareous powder. Calcite veins and crystals are common in some layers. Locally lenticular masses of green shale occur in the red. In size these range up to a foot or two in diameter, and vary in shape from nearly spherical to lenticular masses, narrowing down to thin sheets along cracks. They are undoubtedly due to chemical changes resulting in the leaching of the shale.

Although the majority of this series are soft red shales, there are some hard layers, chiefly near the base, and occasional beds of fine-grained sandstone and flagstones, some of which afford valuable building material. Massive conglomerates along the northwestern border are in part the shoreward correlatives of the red shales.

Evidence that the shales were deposited in shallow water is abundant. Ripple-marks, mud-cracks and rain-drop impressions occur at many horizons. In some quarries imprints of leaves, of tree stems, or the stems themselves are frequently found. The numerous reptile tracks which have made the Newark beds famous occur chiefly in this subdivision. Typical exposures occur along the Raritan River, particularly near New Brunswick.

The Brunswick beds underlie all the region under discussion except that occupied by the Lockatong and Stockton beds and the trap rocks. This area is considerably more than two-thirds of the whole, partly because of the great thickness of the series and partly because the beds have been bent into broad, gentle folds. Standing on the northern end of Sourland plateau one has a magnificent view of the low plain formed on the Brunswick shales, chiefly in the Raritan valley, of the trap ridges which interrupt its continuity and of the enclosing highlands. To the

west is the Hunterdon escarpment, forming the westward limit of the Brunswick shales and marking the line of a great fault, by which the rocks of the plateau have been uplifted several thousand feet.[1]

Thirteen to sixteen miles to the north across the low shale plain are the gneiss highlands, and eight miles northeastward are the curving level crests of the Watchung trap ridges which are interbedded with the Brunswick shales, and beyond which the shale lowland extends. No high ground meets the eye to the east toward New Brunswick thirteen miles away, but to the south rises the Rocky Hill trap ridge, at one point deeply cut through by the Millstone, and there marking the approximate limit of the Brunswick shales. To the southwest there stretches away on either side of the narrow plateau on which we stand, a strip of rolling lowland, likewise underlain by the Brunswick shales.

These rocks also outcrop above the Lockatong series in the northern part of the Hunterdon plateau. They are exposed in high bluffs along the Delaware above and below Frenchtown. It was found that the shales of this area when traced along their strike towards the margin of the formation became rapidly coarser, passing along some horizons into massive conglomerates. It will be remembered that similar changes were found to take place in the Lockatong and Stockton beds, so that within two or three miles of the margin the distinctions between the three subdivisions are largely obliterated.

*Quartzite conglomerates.*—At a number of points along the northwestern boundary of the Newark system there are thick accumulations of massive conglomerates, composed chiefly of quartzite and hard sandstone. Pebbles of limestone, gneiss and shale occur in some layers, but sparingly. All the constituent

[1] The height of the plateau above the red shale plain is not due to the fault, although the latter lies along the foot of the escarpment. As shown by Professor Davis (Proc. Bost. Soc. of Nat. Hist., Vol. XXIV, pp. 365–423) this region was base-leveled in Cretaceous times or thereabouts, and the present topography is due to differential degradation of rock masses of unequal hardness, consequent upon an uplift which affected the whole region.

materials are well rounded, a fact which in the case of the hard quartzites indicates a long period of attrition.

These conglomerates interbedded with sandstones and shales are best exposed in the "pebble bluffs" along the Delaware, above Milford. The conglomerates form lenticular beds which occasionally thin out in the distance of a few rods, to be replaced by beds of different texture. The alternation of the beds betokens shore conditions.

The heaviest accumulations of the quartzite conglomerate underlie the high region stretching northwest from Pittstown and south of Pattenburg. This region is known as "the Barrens" from the nature of the soil, an exceedingly gravelly clay resulting from the disintegration of the conglomerate. Less massive accumulations occur, also, at other points, chiefly south of Clinton, and again four miles north of Peapack, where there is an outlier of this rock called Mount Paul.

*Calcareous conglomerates.*—Conglomerates composed almost entirely of limestone fragments, occur at a number of localities along this border. This rock is in appearance almost the exact counterpart of the famous "Potomac marble" quarried at Point of Rocks, Maryland. The limestone pebbles are usually bluish or gray, sometimes reddish, set in a red mud matrix, so that the rock has a variegated appearance. The average diameter of the larger constituents is six or eight inches, but bowlders three feet in diameter have been seen. The larger fragments are generally rounded, but the majority of the smaller are sharp cornered, or at most subangular. Compared with the pebbles in the quartzite conglomerate, the limestone pebbles are poorly rounded, a fact of some significance in connection with the origin and source of the materials, since with equal transportation, the softer limestones must have been most worn. In many localities this conglomerate is so pure a limestone that it is quarried and burnt for lime for local use.

The relations of these conglomerates to the older rocks along the border are significant. In some localities the calcareous conglomerates adjoin small areas of Palæozoic limestone from

which the materials may have been and probably were derived. In other cases, and this is true of the largest areas, the calcareous conglomerates abut against the gneissic rocks, and for much of this distance it is certain that no limestone occurs between the gneiss and conglomerate, at least not at the surface horizon. Gneissic pebbles, however, occur but rarely in the conglomerate. Substantially the same conditions prevail in the case of the quartzite conglomerate. For the most part it adjoins the gneiss, but gneissic pebbles in it are very rare. The known areas of quartzite from which the materials could have been derived are small, and in general not near the massive conglomerate beds. These facts can be explained on the hypothesis of a fault or series of faults along the northwestern border. But on the Delaware River, at Monroe, Pa., the only locality along the border where even an approach to a good section was found, the conglomerates seem rather to overlap the older rocks at a low angle, than to be faulted against them. In view of the contradictory nature of the evidence, the question of faults along this border is still an open one.

The relation of the conglomerates to the shales is also an interesting and significant one. When traced along the strike the shales and argillites are found to grade into coarser beds which at some horizons become the massive conglomerates near the border. That this is the case has been established beyond a shadow of a doubt by numerous observations. Time and again thin pebbly layers were seen to appear in the shales and to increase in thickness and numbers until they became massive conglomerates. This is true both of the calcareous and of the quartzite conglomerates.

These conglomerates do not, therefore, form a separate horizon but range through the whole formation. Those in the bluffs on the Delaware River above Milford belong with the Brunswick shales. So also do a part of those of the Barrens southwest of Pattenburg. Those of the Barrens north and northwest of Pittstown pass into the Lockatong beds and are therefore older than the conglomerates nearer the Delaware. The pebbly

beds south of Clinton belong in the Stockton series. Both the calcareous and quartzite conglomerates near Pottersville and Peapack belong with the Brunswick beds.

It must be understood that what has been said concerning the above conglomerates does not apply to the conglomerate layers interbedded with shales and sandstones, which occur either along the southeastern part of the formation, near Hopewell or near Stockton. The latter are comparatively thin beds of little importance from a topographical standpoint, and belong to the Stockton series. They present no features of particular interest.

*Thickness of the Newark sedimentary beds.*—All estimates of the thickness of these sedimentary rocks contain an element of uncertainty. This arises from the monotonous character of the beds and the difficulty of detecting and measuring the faults. In addition to several very large dislocations which have been located accurately, a number of smaller fractures have been observed in quarries, railroad cuts, stream bluffs, and other exposures. Most of these could not be traced beyond the point of exposure. After making all possible allowance for known faults, I am compelled to admit that the facts in hand indicate a vastly greater thickness than has usually been supposed.

The thickness of the Stockton beds between Trenton and Wilburtha seems to be 2300 feet. No estimates can be made in the area near Hopewell, since only the upper part of the series, 650 feet or so, is there exposed. At Brookville below Stockton the base of the formation is brought to the surface by a fault and the thickness seems to be 4700 feet. No positive evidence of a fault could be found within this area to account for the greater thickness as compared with the belt near Trenton, whereas there is slight evidence that the whole series is not found near the latter place.

The thickness of the Lockatong beds is best shown on Hunterdon plateau. Here the upper and lower limits can be carefully located. The dip is more than ordinarily uniform and outcrops are sufficiently numerous to prevent any great error in

the calculation. More than this, the sweeping curve of these rocks, the uniform width of the belt, and the possibility of tracing certain subordinate but well-marked layers continuously along the strike, precludes the idea that any great part of its apparent thickness is due to repetition by faulting. Three independent measurements, made at intervals several miles apart gave results of 3540 feet, 3450 feet, and 3500 feet respectively.

Three measurements of the thickness of these same beds in the Sourland plateau gave substantially the same results, *i. e.*, 3600 feet, 3650 feet, and 3660 feet. The fact that for a part of the distance a great trap sheet has been intruded into these beds and elsewhere has caused changes in the adjoining red shales, makes it a little more difficult to measure these beds. The fact that the thickness of these beds in Sourland plateau agrees so closely with that of the same beds on Hunterdon plateau is further reason for believing that the figures here given represent very closely the actual thickness. To suppose otherwise is to assume that these two separate areas are each traversed by faults, whose throw, by a remarkable coincidence, is almost exactly the same, but no traces of which have been discovered by areal work of the most detailed character.

The thickness of the Lockatong beds of the belt near Ewingville and Princeton seems to be only about half of that in the other two regions, *i. e.*, 1700 to 1800 feet. As noted above, the same relative thinness was observed in the Stockton beds near Trenton as compared with those further north. The explanation may lie in the fact that the beds of the thinner belts are nearer the old shore line than the others. Stratified deposits have the form of an unsymmetrical lens which thins out very rapidly shoreward and very gradually seaward. It is to be expected, therefore, that the thickness of this belt would be somewhat less than that of the others, but it may be fairly questioned whether in the case of such fine deposits the difference would be so great as that indicated by the figures.

The thickness of the Brunswick beds is even more difficult

to estimate accurately. This is due to the uniformity of the red shale, which renders it very difficult to detect the presence of faults, to the folded structure, and to the fact that the entire thickness is not present in this part of the state.

West of Ringoes the shales form a syncline whose axis plunges northwest. Estimates made here show that between 7000 and 8000 feet of shales are involved in this folding. Between the mouth of Lawrence Brook, east of New Brunswick, where the shales disappear beneath the Cretaceous cover, and the base of First mountain, back of Bound Brook, the beds are 10,000 feet thick, provided there are no faults in the intervening region. In the Raritan River bluffs below New Brunswick three fault breccias were found, but nothing is known as to the amount of dislocation beyond the fact that it was not sufficient to expose the Lockatong beds which are here at a horizon about 1000 feet lower. From the amount of disturbance and crushing which is known to accompany great faults in other parts of this area, the presumption is that these are small. A deduction of 1000 feet from the above estimate would seem to be ample for these and any undiscovered fractures. Nine thousand feet, however, is not enough, since neither the base nor the top of the Brunswick beds is included in this section. They certainly extend for 2000 to 3000 feet above the base of First Mountain. In the light of the present facts an estimated thickness of 12000 feet for the Brunswick shales does not appear excessive, although in view of the uncertainties connected with the structure, too much emphasis must not be placed upon it.

The total thickness, therefore, of the sedimentary rocks of the Newark system in western New Jersey seems to be about 20,000 feet. These figures are so great that one naturally hesitates to accept them, but the facts, so far as known, do not permit any other interpretation. I began my work feeling confident that the thickness of the beds was much less than this, and that they were many times repeated by faults. However, many of the faults found cross the beds at such angles as to be ineffective in repeating the strata. Furthermore, the fact that the

three estimates of the thickness of the Lockatong beds in the Hunterdon plateau, where the outcrop is so curved, agree closely one with another, and also with the various estimates of the same beds on Sourland plateau, make it improbable that the great thickness of this series is due to faults. So, too, the thickness of a *part* of the Brunswick shales involved in a synclinal fold can be accurately determined and the possibility of the faulting there eliminated. Again a narrow trap dike was traced uninterruptedly from the back of Sourland Mountain near Rocktown to Copper Hill, a distance of five miles. The dike crosses the strike at an angle of 45° and the thickness of the shales thus traversed is between 6000 and 7000 feet. There are reasons which cannot here be specified for concluding that the Sourland trap sheet, and therefore the dike, were intruded into the shales during Newark time, and before or contemporaneous with the tilting. If these reasons are valid the continuity of the dike is proof that the shales traversed by it are not cut by faults along the strike. Since such great thicknesses prevail in these beds, which are only a part of the whole system, there is the more reason for accepting the figures given above. It can certainly be claimed for these estimates that they rest upon a much larger basis of fact than any previous figures.

*Trap rock.*—The trap rocks in the Newark series have been described by various writers[1] who have shown that both intrusive and extrusive sheets occur. In this connection I desire briefly to call attention to a few new facts which confirm the conclusions of some of the earlier observers.

Three narrow dikes were found to start from the upper surface of the Sourland Mountain trap mass, and were traced through the overlying shales for several miles. Their existence proves conclusively that this sheet is intrusive. It would naturally follow that the continuation of Sourland Mountain in Pennsylvania is also intrusive, although Lyman[2] has published very positive views to the contrary. Moreover the fact that the trap

[1] Chiefly Cook, Russell, Davis, Darton, Iddings.

[2] Pennsylvania State Geol. Surv., Final Rept., Vol. III, Pt. II, p. 262.

locally cuts across shales for a total of 1800 feet is certainly well established. The Rocky Hill trap sheet does not follow the strike of the shales but crosses them more or less obliquely. Where it terminates near Hopewell it is 6000 feet[1] or more above the base of the Brunswick shales, whereas at Deans station where it disappears beneath the Cretaceous beds, it is 1500 feet below them. If we are correct in assuming that Rocky Hill is a continuation of the Palisades, the sheet descends still further, since along the Hudson it is found in beds which certainly belong to the Stockton series. A recently dug quarry opposite Point Pleasant, Pa., on the Delaware, shows that the trap mass there crosses the shales at a steep angle and is also intrusive.

Near Sand Brook village, southwest of Flemington, there is a low horseshoe-shaped ridge of trap formed by the outcropping edges of a synclinal sheet whose axis plunges northwestward. This sheet is extrusive in origin, as is shown by the following facts: (*a*) It is conformable to the enclosing shale; (*b*) the upper surface is everywhere extremely vesicular and only the lower portion is dense and full grained; (*c*) the overlying shale is absolutely unaltered within one and two feet of the trap; (*d*) red shale has filled some of the cavities of the vesicular trap, and in one locality a thin layer of finely comminuted trap, glass and red shale lies between the normal red shale and the vesicular trap. This sheet has not heretofore been described or shown upon published maps.

*Metamorphosed shales.*—Numerous allusions are made in the earlier reports to metamorphosed or "baked" shales associated with the trap and in some cases found far away from any igneous rocks. The black argillites of the Lockatong series have been called "baked shales" by some writers and their hardness and blackness ascribed to the contact with the trap, although no igneous rocks occur near them. Metamorphosed shales do occur in connection with the larger in usive trap masses, but all the

[1] These figures are correct just so far as the above given figures of the total thickness are reliable.

hard black shales are not "baked" shales. The most marked macroscopic changes induced in the altered shales are (*a*) a greater or less induration, (*b*) change in color,—the red shales in general becoming purple and then a blue-black or green near the trap, and (*c*) the development of secondary minerals,—very commonly epidote and tourmaline. Where the change has not produced definite crystal forms or nodules, an incipient segregation has often occurred, giving the rock a more or less mottled aspect, and on weathered surfaces a warty appearance, although this latter characteristic is not limited to the metamorphosed beds, but occurs in some layers of the Lockatong beds far from any known trap.

Of these three changes the third is believed to be the most significant. Mere induration or change of color do not necessarily signify "baking," but when all three occur together and only in layers in close proximity to certain trap sheets, proved to be intrusive by their structural relations, the changes can be safely ascribed to the igneous rock. Many of the baked shales, on weathering, become a pale blue or ashy gray color, a tinge never taken by other layers.

Metamorphosed shales occur both above and below the trap of Sourland Mountain and are well exposed in the bluffs near Lambertville. They are associated also with the Rocky Hill sheet, fine exposures being found along the canal near Rocky Hill village. In fact all the intrusive trap sheets are surrounded by shales which have been more or less altered in texture, color, and mineralogical constitution. Baked shales surely exist near some of the trap sheets, but all hard, black shales of the system are not baked, as was formerly supposed.

*Unclassified beds.*—It has been impossible to classify definitely the beds of a small area between Mount Airy, Lambertville, and the mouth of Alexsocken Creek. Their structure is complex, the dips vary greatly in direction and amount, and in many cases they are crushed and distorted. Two small masses of trap occur within the area, and some of the beds are certainly metamorphosed. Whether they belong to the Lockatong or Bruns-

wick division I am unable to say on account of the complexity of structure and their varied lithological character.

## STRUCTURE.

*Folds.*—The general structure is that of a faulted monocline, the beds of which trend N. 30° E., and dip 12° or 15° to the northwestward. Examined in more detail the structure is seen to depart locally from the monocline. Several broad, gentle flexures occur, in addition to a few sharply marked folds in the vicinity of the intrusive traps and greater fault lines. A good example of the former is seen in the shales of the Hunterdon plateau, where the beds are so inclined that their outcropping edges describe a great curve parallel on the east and southeast to the escarpment of the plateau. The structure is a shallow syncline, whose axis is inclined to the northwest. Low folds were found along the valley of the Raritan, particularly in the region north of Somerville. From New Brunswick to Bound Brook the dip is quite uniformly to the northwestward, averaging 10°, but to the west the monocline is interrupted by gentle flexures and swells which are difficult to trace because of the absence of individuality in the layers. The broad outcrop of the Brunswick shales in the Raritan valley is due in large part to these low folds.

More definite folds—all synclines—occur (*a*) near the Sand Brook trap sheet southwest of Flemington, (*b*) the New Germantown trap sheet, and (*c*) the Watchung traps whose great crescent curves are due to the synclinal structure of the inclosing shales.[1] In consequence of this fold the beds which outcrop near the crystallines along Mine Brook, northeast of Bedminster are at the same horizon as those between the two trap sheets back of Plainfield and Bound Brook.

Several examples of sharp folds occur near Glen Moore southwest of Hopewell and not far from the end of Rocky Hill ridge. Other instances were noted near the faults.

The beds of the Stockton and Lockatong divisions are most

[1] COOK, DARTON, DAVIS, et al.

constant in dip and strike, so that the monoclinal structure is most marked in these belts. The Brunswick shales are marked by shallow folds, some covering an area of several square miles. These combined with a fortunate arrangement of faults, have greatly increased the area of red shale outcrop, and so permitted the formation of the broad, rolling lowland, so characteristic of the greater part of the Newark system.[a]

*Faults.*—The location of the most important faults by which these rocks are traversed is shown on the map. The Hopewell fault, heretofore unrecognized, extends in a sinuous course from near the Delaware River by Harbourtown, Hopewell, and thence along the foot of the Sourland plateau escarpment, passing a little west of Flagtown station on the Lehigh Valley Railroad. It probably crosses into Pennsylvania, but its exact location at the Delaware River could not be definitely determined.

The evidence of faulting along this line is as follows: (*a*) the repetition of the strata; (*b*) crushed and contorted shales, slickensided surfaces or overthrown dips at every exposure along or near the fault line; (*c*) diversity of structure, dip and strike —on opposite sides of the fault line; (*d*) contrasts in topography and the termination of ridges at the fracture. The repetition of the strata has already been alluded to in describing the rocks. The map shows how the Stockton, Lockatong and Brunswick beds are repeated, the beds to the northwest having been uplifted. In the bed of every stream crossing the fault, evidence of the fracture was found in the crushed and slickensided condition of the rocks, but the fault plane was nowhere exposed. Locally the rock has been so greatly sheared as to destroy all traces of the bedding planes. Very marked overthrown dips occur in a cut just west of Flagtown station, which increase in steepness towards the fracture. Folds in the Brunswick beds on the southeast side terminate abruptly against the fault and do not affect the beds on the opposite side. The high Sourland plateau composed of the hard trap and resistant

[a] The details of structure, which must be omitted here, are given in the Annual Report of the State Geologist of New Jersey for 1896, pp. 72–78.

Lockatong argillite terminates abruptly where the fault crosses the strike of its beds. The height and prominence of the escarpment north of Skillman station is due to the contrast in hardness of the Lockatong and Brunswick shales brought into juxtaposition by the fracture.

The dislocation has been sufficient to bring to the surface the upper part of the Stockton beds, and place them side by side with the middle layers of the Brunswick shales. On the basis of the above estimates of thickness the throw cannot be less than 10,000 feet. The nade of the fault cannot be determined, since the fracture is nowhere exposed in section and its location can rarely be determined within fifty yards. North of Flagtown, where the Brunswick shales occur on both sides of the fracture, its course could not be determined.

*Flemington fault.*—The course of this fault previously noted by other workers[1] is best seen by reference to the map. It is located in the bluffs of the Delaware River by the juxtaposition of the coarse arkose conglomerate (Stockton) with the black argillite (Lockatong) a mile or more south of Stockton. The line of dislocation is concealed by the talus of a small ravine. From this point it extends in a northeasterly direction for three miles, thence curving a little to the north so as to pass east of Headquarters, southeast of Sand Brook and a mile west of the center of Flemington. For much of this distance it extends along the foot of the Hunterdon plateau escarpment.[2] For several miles north of Flemington its exact location becomes doubtful owing to the similarity of the adjoining beds, but one or perhaps both of the two faults along the border west of Cushetunk Mountain mark its northern extension. There is some reason for believing that the trap of Round mountain, south of Cushetunk Mountain, has ascended along the fracture, but this is not conclusively proven.

The evidence of this fault is as complete as in the case of

[1] LEWIS, DARTON, NASON, LYMAN, and others.

[2] On a "conjectural" map of the Newark formation of New Jersey (Lyman, Pa., Geol. Surv. Summary Final Report, Vol. III, Pt. II, Plate 597, also Proc. Am.

the Hopewell fault. It consists of (*a*) repetition of the strata, (*b*) diversity of structure and topography on the two sides, (*c*) local disturbances, crushed beds, overthrown dips and slickensides.

The uplift was on the northwest and was sufficient to bring to the surface the base of the Stockton beds and just across the river in Pennsylvania, the Palæozoic floor on which the Newark beds rest. East of Headquarters and Sergeantsville, lower members of the Stockton series abut against beds of the Brunswick series apparently 2600 feet above the base. If we accept the thicknesses already given, the throw of the Flemington fault near Headquarters is not less than 10,000 feet.

Half a mile east of Sand Brook village a small fault splits off from the main fracture. By it a part of the Lockatong beds of the plateau have been downthrown so that they occur to the east, and apparently below the Stockton beds. The beds between the two faults are much confused in structure.

Another and larger split fault was observed to branch from the main fracture between Headquarters and Dilt's Corners. It crosses the Delaware about midway between Stockton and Lambertville, and from a cursory examination I am inclined to believe that it joins the Flemington fault again in Pennsylvania about a mile from the river. The rocks of this block belong to the Lockatong and Stockton series with some intrusive trap masses. The general dip is south of west, although near the faults there is much diversity. The beds on the east and southeast have been downthrown relatively to the others. The combined throw of this fault and the Flemington fault is about equal to that of the latter further north.

Faults of a few feet throw have been noted in not a few cases in quarries, railroad cuts and other exposures. In still other cases the amount of dislocation could not be determined, but they could not be traced beyond the point of exposure, and the throw

Philos. Soc., Vol. XXXIII, p. 194), the fault has been located several miles from its proper position. A similar error is found on the map in Proc. Am. Philos. Soc., XXXI, No. 142.

probably was not great. It is not believed that there are other faults in the area examined whose throw is even one-tenth that of the two great ones. I have alluded elsewhere to the possibility of faults along the northwestern border. Two are shown upon the map and others are believed to exist, but are not mapped. The recurving horn of the Second Watchung Mountain is quite certainly separated from the crystallines by a fault. Further investigation of these points together with the study of the region not yet examined, is now in progress.

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# THE TOPOGRAPHY OF CALIFORNIA.

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## INTRODUCTION.

THE writer has recently completed a relief map of California on a scale of 1 inch to 12 miles, and a vertical scale of 1 inch to 12,000 feet. This makes it about 4 by 5 feet square, and the highest peaks nearly 1¼ inches high.

The accompanying plate was taken from a photograph of this map, and illustrates the main topographic features of the state. To give some idea of the accuracy of the topography as shown, the method of making the map is given.

*Method of making the relief map.*—As no topographic map of the state was available, all the maps, levels, and other topographic data were collected and a contour map of the state compiled.

The topographic data were obtained principally from maps of the State Mining Bureau,[1] the United States Geological Survey, the United States Coast and Geodetic Survey, various reconnaissance surveys, and from topographic descriptions and railway surveys, and from elevations of peaks, passes, and places obtained from various sources, both published and unpublished.

The gross relief of the state was then built up on a rigid wooden base by cutting out card-boards of the proper thickness in the shape of each 1000-foot contour and nailing them in place one on top of the other. The steps or terraces made by the card-board and the minor details of relief were then filled in with wax.[2] The best reference maps of the particular area being modeled, were kept constantly at hand during the process of filling in the details. After the completion of the original, a negative was made in plaster of Paris, and from this the positives are made. The completed relief map represents about six months of continuous and careful work. It shows the relief with all the detail which the scale permits except in those parts of the state in which topographic data are wanting. But even in these parts the drainage made it possible to show the general features fairly well.

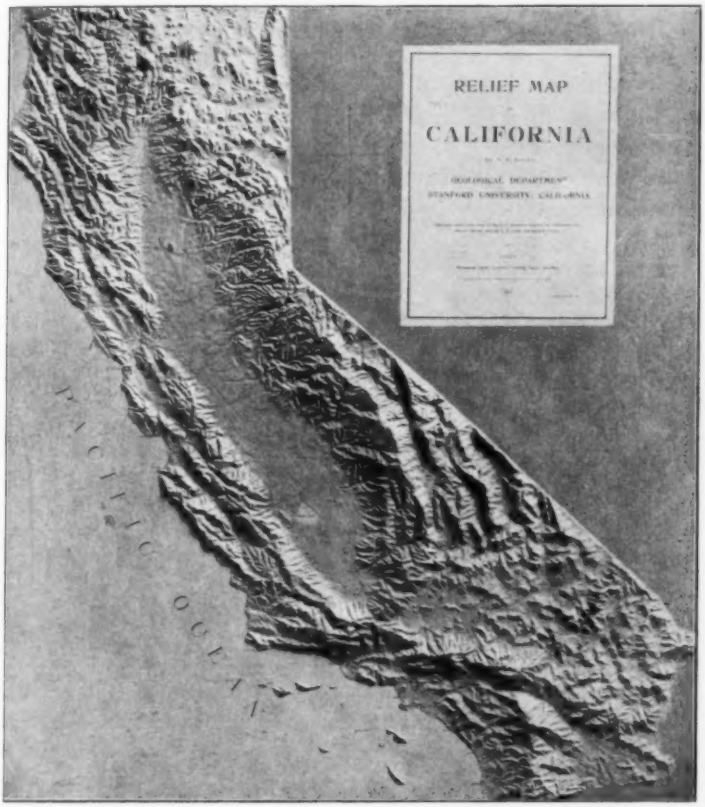
## TOPOGRAPHIC REGIONS.

*General features.*—The northern part of the state is largely composed of three parallel and almost equally extensive topographic belts running lengthwise the state. These belts are the Sierra Nevada on the east, the California Valley in the center, and the Coast Ranges on the west. The Sierra Nevada, with its main crest from 6000 to 13,000 feet above tide and its highest peak reaching an elevation of nearly 15,000 feet, is the highest and most prominent mountain system of the state. The continuation of the Sierra Nevada in extreme northern California is

[1] The Preliminary Mineralogical and Geological Map of California, issued in 1891 by the State Mining Bureau, was used as a base.

[2] This wax was composed of 16 parts of beeswax, 8 of cornstarch, 4 of Venice turpentine, 1 of Venetian red, and 1 of sweet oil.

called the Cascade and the Lava Sheet mountains. The mountains next in importance to the Sierra Nevada are the Coast Ranges, which have an average elevation of about 4000 feet, a




width of 50 to 100 miles, and with the exception of a break at San Francisco Bay, extend along the coast for the full length of the state. The Coast Ranges, however, are more or less broken at a number of places, thus giving rise to rather distinct groups of mountains which have received special names. The southern

end of the Sierra Nevada makes a sharp curve to the west, meeting and uniting at Téjon Pass with an eastward curving branch of the Coast Ranges.

The Klamath Mountains, occupying the northwestern part of the state, unite the Coast Ranges and the Cascade Mountains. Between these mountain ranges lies the California Valley, which extends nearly northwest and southeast, and is about 400 miles long by 50 miles wide. It is drained by the Sacramento and San Joaquin rivers.

The southern part of the state has three distinct topographic areas, one of which lies along or near the coast, and is the continuation of the Coast Ranges under the name of the Sierra Madre Mountains. This mountain system is composed of several different ranges, the principal ones being the San Gabriel, the San Bernardino, and the San Jacinto. The breaks between these mountain ranges are not complete, so the system is prolonged by successive ranges to and beyond the southern boundary of California.

Another of these topographic districts is the northern part of southeastern California; this is composed of narrow and parallel mountains and valleys running north and south. The mountains are high, and the valleys narrow and closed. Farther to the south the relief is composed of irregularly grouped and rather low mountains, flat intervening table-lands and closed drainage basins.

*The Sierra Nevada.*—The Sierra Nevada is essentially a single mountain chain with a summit line deviating but little from the general trend of the mountains. This summit line is near the eastern edge of the range, except in the extreme northern part where it extends nearer to the western limit of the mountains. The eastern slope of the mountains is especially abrupt. The fall from Mt. Whitney to Owen's Valley, a distance of ten miles, is about 10,000 feet.[1] The western slope approximates a long, broad, inclined plain, furrowed deeply and closely by numerous canyons. By observing the accompanying plate it may be seen

[1] J. D. WHITNEY, Geological Survey of California, Vol. I, p. 456.

that if these canyons were filled level to the tops of the ridges the result would be an irregular, slightly warped, tilted plain. In general the grade of this tilted plain is quite regular from the low elevation of the California Valley to the top of the mountains. This western slope was probably once a region worn down almost to base level or to a peneplain. By the uplift of the mountains a great fault was developed along the eastern face and the whole Sierra crust-block tilted to the westward. The streams quickened by the uplift again set to work on the peneplain and carved it to its present condition. According to Professor Joseph Le Conte:[1]

> The Sierra was formed, as we now know, by lateral crushing and strata-folding at the end of the Jurassic. But during the long ages of the Cretaceous and Tertiary this range was cut down to very moderate height. . . . . The rivers by long work had finally reached their base-levels and rested. The scenery had assumed all the features of an old topography, with its gently flowing curves. . . . . At the end of the Tertiary came the great lava streams running down the river channels and displacing the rivers; the heaving up of the Sierra crust-block on its eastern side, forming the great fault-cliff there and transferring the crest to the extreme eastern margin; the great increase of the western slope and the consequent rejuvenescence of the vital energy of the rivers; the consequent down-cutting of these to form the present deep canyons and the resulting wild, almost savage, scenery of these mountains.

J. S. Diller's researches in the northern part of the Sierra Nevada further strengthen these theories, as the following quotations from him will show:

> A study of the ancient topographic features upon the borders of the Sacramento valley, in the Klamath Mountains, and upon the western slope of the Sierra Nevada, shows that during the earlier portion of the auriferous gravel period northern California, by long-continued degradation, was finally reduced approximately to base-level conditions. The mountain ranges were low, and the scenery was everywhere characterized by gently flowing slopes. . . . . The topographic revolution consisted in the development out of such conditions of the conspicuous mountain ranges of today. The northern end of the Sierra Nevada has since been raised at least 4000 feet, and possibly as much as 7000 feet, and a fault of over 3000 feet developed along the eastern

[1] Bull. Geol. Soc. Am., Vol. II, pp. 327–328.

face of that portion of the range. . . . . The amount of uplift decreases rapidly towards the Sacramento valley.[1]

Mr. Waldemar Lindgren thinks the Sierra Nevada was eroded to, or almost to, a peneplain during Cretaceous times, and that the mountains elevated in a later Cretaceous period were worn down during Tertiary times merely to a gentle topography.[2]

Of the origin of the range he says:

At this time[3] . . . . the first break took place, separating the Sierra Nevada from the interior basin. The orogenic disturbance was probably of a twofold character. It included the tilting up of the whole region between the Wasatch and the Pacific in arching form, and a simultaneous breaking in and settling down of the higher portions of the arch. Thus the Sierra Nevada crust fragment was formed, the larger part of which has ever since remained a comparatively rigid block. Along the eastern margin the system of fractures was outlined which toward the close of the Tertiary was to be still further emphasized.

The evidences that the Sierra Nevada is a tilted and eroded peneplain with a fault line along its eastern edge may be summed up as follows:

(1) The present features of the western slope of the mountains resemble a tilted and dissected peneplain. The precipitous slope on the eastern side marks the fault line.

(2) Fossil plants,[4] which indicate a low altitude at the time of the deposition, have been found in the auriferous gravels in the northern part of the Sierra Nevada.

(3) The auriferous gravels now found in the old river beds along the western slope of the Sierra Nevada must have been deposited in streams flowing down gentle grades.

(4) Many of the old river valleys are terraced, showing successive stages of elevation as well as low stream grades.[5]

(5) The present rivers flow directly across the upturned edges

[1] 14th Ann. Rept. U. S. Geol. Surv., Part II, p. 433.

[2] JOUR. GEOL., Vol. IV, pp. 882, 894, 897, and 898.

[3] JOUR. GEOL., Vol. IV, p. 894.

[4] J. S. DILLER, 14th Ann. Rept. U. S. Geol. Surv., pp. 421–422.

[5] J. S. DILLER, 8th Ann. Rept. U. S. Geol. Surv., Part I, p. 429.

of Mesozoic and Palæozoic beds on the lower slopes of the mountains.

(6) The Tertiary lavas on the western slope of the Sierras cover a gentle topography.[1]

It has been noted that the Sierra Nevada is now deeply carved by the streams flowing down its western slope. The canyons vary in depth from a few hundred to six thousand feet; their walls are very steep, and in places perpendicular; in the Yosemite and King's River canyons there are perpendicular walls over three thousand feet high.[2] These canyons run approximately at right angles to the trend of the mountains and parallel with each other. This direction and parallelism is especially true of the larger canyons, which form a series quite regularly spaced throughout the length of the mountains.

The parallelism of the canyons is due principally to the two causes of uniform direction of tilting and the parallel system of fault and fissure lines. It is generally conceded that the great canyons, as well as many smaller ones, run along fault lines.[3]

And it has been observed[4] that often the canyon following one system of fissures crosses over to another system and follows it. G. F. Becker has pointed out that in places these fissure lines are so close together as to amount to shattered zones, and that the main fissure systems cross at right angles.[5]

So a probable explanation for such places as King's River and Yosemite Valleys is that they are the locations of shattered zones removed by erosion, so that the fissures bounding the shattered zone now form the faces of the perpendicular exposed valley or canyon walls.

It may be seen from the accompanying plate that the canyons west of Lake Tahoe, especially North Yuba River, Middle

[1] WALDEMAR LINDGREN, JOUR. GEOL., Vol. IV, p. 897.

[2] J. D. WHITNEY, Geol. Surv. Calif., Vol. I, pp. 410 and 421. JOHN MUIR, Century Magazine, Vol. XVIII, p. 488, and Vol. XXI, p. 80.

[3] G. F. BECKER, Bull. Geol. Soc. Am., Vol. II, p. 68. The Rocks of the Sierra Nevada, by H. W. TURNER, 14th Ann. Rept. U. S. Geol. Surv., p. 443.

[4] G. F. BECKER, Bull. Geol. Soc. Am., Vol. II, p. 68.

[5] Bull. Geol. Soc. Am., Vol. II, pp. 50–51 and 68.

Yuba River, Bear River, North Fork and Middle Fork of American River, receive almost all their drainage from the north side, which would seem to indicate that each of these main canyons followed a fault line, and that in addition to the westward tilting of the mountain mass these separate smaller blocks between the canyons tilted to the southward also.

The regularity of the canyon system and the westward-sloping, eroded plain is somewhat more broken to the south of Merced River, where the principal rivers, *i. e.*, the San Joaquin, the Kings, the Kaweah, and the Kern, have a wide range of tributary streams and have carved out more basin-like drainage areas. It appears that the southern end of the Sierras has existed longer as a mountain range; and also that the Tertiary lava flows that spread over northeastern California as far south as Merced River did not bury the drainage systems farther to the south. Thus it seems that these drainage systems are older and naturally more basin-like or collected in larger groups.

The Kern River is the first to break the general westward course and flow south for most of its length before turning towards the California Valley. The parallelism in the tributaries of the upper course of the Kern forcibly suggests faulting and folding along parallel north and south lines, and probably southward tilting also, to guide the streams.

*Cascade region.*—The northeast part of California is a table-land with cone-shaped peaks here and there rising above the general level. Toward the east the flat table-lands are broken by ridges extending north and south which usually have a steep slope on the east side and a gentle slope on the west side. The lava outflows that spread over southeastern Oregon extend in a sheet over this area forming the table-land. The cone-shaped peaks are lava outpourings, where the lava flows were concentrated at points. Mt. Shasta and Lassen peaks are notable examples of volcanic cones on the western side of this area. In the northeast corner of this area fault lines are prolonged southward from a fault system extended down from southeastern

Oregon.[1] Small orographic blocks between these fault lines are usually tilted westward and form ridges and basins such as Warner Mountains, Alkali Lakes basin, and Goose Lake basin.

*Klamath Mountains.*—To the west of the lava sheet lies the irregular group of mountains known as the Klamath Mountains.

This region has long been subjected to erosion, and to oscillations[2] from archipelago to high land elevations. The outpouring of lava and accumulations of sedimentary beds on the flanks of the granitic core and the irregular tilting, and faulting, have produced a complex mountain mass and an area of tortuous stream courses.

*The Coast Ranges.*—Joining the Klamath Mountains on the southwest, and extending southward along the coast are the Coast Ranges. The typical part of this system lies west of the California Valley. This part of the Coast Ranges is composed of numerous parallel ranges, ridges, valleys, and canyons which extend in almost straight lines along and parallel with the coast. The elevations of opposite ranges are usually approximately the same. At places the opposite ranges are completely separated, but usually they coalesce, only to break again along the same lines. Thus along any given line through and parallel with the ranges, a topographic feature may disappear but it occurs again after a short break. These parallel lines of topographic features show the close kinship of the ranges and extensive fault lines and folding axes.

[1] J. C. RUSSELL, A Geological Reconnaissance in Southern Oregon. 4th Ann. Rept. U. S. Geol. Surv., pp. 436–464.

[2] "At the close of the Taylorville Jurassic there was an upheaval by which the Klamath Mountains were outlined."—J. S. DILLER, Bull. Soc. Am., Vol. IV, p. 224.

"During the Cretaceous period, especially during that portion represented by the Shasta-Chico beds, northern California gradually subsided. . . . . The Klamath Mountains during a part of this time, at least, formed an island."—J. S. DILLER, Tertiary Revolution in the Topography of the Pacific Coast. 14th Ann. Rept. U. S. Geol. Surv. 1892–3, pp. 23–24.

"During Miocene times . . . . the Klamath Mountains were low with gentle slopes as compared with those of the present ranges; and the streams flowed down their flanks in broad shallow valleys instead of in deep canyons as they do now."—JOUR. GEOL., Vol. II, p. 44; also 14th Ann. Rept. U. S. Geol Surv., p. 423.

Lawson has shown[1] that a considerable part of this region has been eroded to base level and when this area was elevated to a plateau, erosion followed the weak lines, dissecting the plateau until only the tops of ridges are now left as evidence of the once leveled region. The larger ranges and valleys, however, appear to be of orogenic rather than erosive origin. Local shifting of land elevations or the irregular tilting of some small blocks of the earth's crust has divided some of the larger valleys such as Russian River—Petaluma Valley, and the Santa Clara-San Benito Valley. In both cases the adjoining valleys are continuous, but from tilting of earth-crust blocks the valleys are slightly divided so that their drainage runs into the ocean or bays at different places. An elevation of the southern end of the Santa Clara Valley has turned the San Benito River to one side so that it now flows through a narrow outlet into the Bay of Monterey instead of continuing in the straight and open valley to the north and emptying into San Francisco Bay. Similarly the southward continuation of the Russian River Valley leading into San Pablo Bay is so tilted as to throw the Russian River drainage to one side through a narrow outlet into the ocean. Such local tilting of the earth's crust causing the flooding of valleys is the origin of San Francisco Bay, Tomales Bay,[2] and probably[3] Monterey Bay. This shifting has been so late that the effects of subsidence are plainly shown in adjoining valleys. Tomales Bay[4] is clearly one of these drowned valleys. It is a long riverlike bay that is about three-quarters of a mile in width and fifteen miles long. The valley of the bay continues to the southward until it reaches the ocean again.

*The great valley of California.*—The California Valley, lying between the described mountain systems, is a low, level area about 400 miles long and 50 miles wide. The width of the valley is quite regular throughout, but is somewhat greater at the southern end and a little north of the center. At this latter

[1] Bull. Dept. Geol. Univ. Calif., Vol. I, No. 8, pp. 242–244.
[2] A. C. Lawson, Bull. Dept. Geol. Univ. Calif., Vol. I, pp. 263–269.
[3] A. C. Lawson, Bull. Dept. Geol. Univ. Calif., Vol. I, p. 59.
[4] A. C. Lawson, Bull. Dept. Geol. Univ. Calif., Vol. I, No. 8, p. 264.

place the San Joaquin and Sacramento rivers, which are the principal streams of the valley, are confluent and flow westward through the straits of Carquinez, thence through San Francisco Bay into the ocean. Well borings at different places over the valley show the upper 1000 feet or more of the valley deposits to be fluviatile and subaërial,[1] for the strata consists of alternating beds of sand, clay, and gravel, and in places contain loess-like[2] strata and organic remains[3] of land and fresh water animals.

The origin and growth of the valley, as stated by F. L. Ransome, is in brief as follows:[4]

> With the post-Pliocene elevation of the crest of the Sierra and with the gradual upward diastrophic movement of the Coast Ranges during Pleistocene times . . . . the valley became closed in by mountains as we find it at the present day . . . . .
>
> All through Pleistocene and recent times, the streams flowing down from the Sierra, and from the eastern slope of the coast ranges have been pouring detritus into the deepening valley, depositing the coarser materials in broad alluvial fans and carrying the finer silt farther out to be spread over the plain in flood seasons.

So it seems that this area has been largely built up at equal pace with its subsidence, usually existing as a low, marshy tract, retaining a large part of the detritus brought down from the Sierras and Coast Ranges. The southern end of the valley is a low, marshy area, with no well-defined outlet, and at the present time retains all the detritus and sediment brought there from the adjoining mountains.

*The Sierra Madre Mountains.*—It has been noted that west of the California Valley the axes of the coast ranges run nearly northwest and southeast, but the further continuation of the coast ranges to the southward is first marked by almost east and west axes, which are in turn followed by ranges running northwest and southeast. In each case the coast line turns and runs parallel with the axes of the mountains along the coast. The

[1] Eighth Ann. Report Calif. State Mineralogist, 1888, pp. 558–560; Tenth Report, 1890, pp. 548–564; Twelfth Report, 1893, pp. 350–351.

[2] Bull. No. 3, Calif. State Mining Bureau, p. 16.

[3] Bull. No. 3, Calif. State Mining Bureau, pp. 20 and 68.

[4] The Great Valley of Calif., Bull. Dept. Geol. Univ. Calif., Vol. I, p. 398.

islands off the coast of southern California have their longer axes lying in the same direction as the opposite shore line and mountain range, showing that these islands belong to the system of orogenic movements that created the mountain ranges of the mainland and are remnants of partly submerged mountain ranges.

The parallel grouping of mountain chains, which is so prominent a feature of the Coast Ranges to the north, is much less marked in the Sierra Madre Mountains, where the mountain system consists essentially of successive single ranges, somewhat elongated in the axial direction, but consisting of a central mass, from which spurs radiate in all directions.

*Owens River—Death Valley district.*—This topographic region is the southern end of the Great Basin mountain system. The mountains and valleys of this system are parallel and run north and south. The mountains are usually high, and the valleys low and narrow. This topography is one of block faulting, which gives the great extremes in elevation and the narrow straight lines of mountain ranges and valleys. Drainage is now poorly defined, because the rainfall is so light that no permanent streams of any considerable length exist. Nearly every valley is a closed basin that has been filled to a considerable depth with detritus from the adjoining mountains. Death Valley, though having this usual filling of detritus, is, at its lowest place, 480 feet[1] below sea level.

*Mohave—Colorado River district.*—Southeastern California has rather low, irregular-shaped mountains, flat table-lands, and low, closed drainage basins. Nearly all the mountains and hills have the appearance of being partially buried, so that only their tops project, island-like, above the surrounding plains. In this region there is but little or no drainage to carry off the disintegrated rocks. The débris, blown and drifted around, fills the valleys until only the tops of the hills project above the débris-covered plain. This area is a meeting point for several mountain systems, and therefore has a mixed arrangement of its mountains.

[1] North American Fauna, No. 7, Death Valley Expedition, Part II, p. 367.

MINOR TOPOGRAPHIC FEATURES.

Besides the general topographic features which may be seen from the accompanying plate, there are others too small to show, but nevertheless of considerable importance.

*Terraces.*—There are, along almost the whole length of the coast, benches and rounding bluffs of more or less prominence. Some of these terraces are only seen after close observation, while others form benches of considerable width.

As shown by Lawson,[1] these are marks of old seashores, and show successive elevations of the land through Quarternary times.

*Mesas and table-lands.*—These are marked features of the coastal plain north of San Diego, and occur on the sides of river valleys farther to the north. This characteristic feature may be observed in the Salinas Valley at King City. Lawson has shown[2] that the Pliocene corresponds to a time of general subsidence of the coast, when the sea encroached upon the land, flooding the low coast lands and valleys. These flooded coast margins and valleys thus became the dumping ground for the sediment from neighboring lands until the accumulations grew to great thickness. Then, when the land rose and erosion carved this accumulated sediment, mesas and table-lands were left.

*Alluvial cones and fans.*—In parts of the state where the rainfall is light or not sufficient to carry the disintegrated rocks any considerable distance it is common to see along the valleys, at the mouths of mountain canyons, the valley built up higher, so that the mouth of the canyon is buried beneath a cone of débris. The writer has observed this in the White Mountains near the California-Nevada state line, where, standing at a commanding place some five or six miles from the mouth of a large canyon, it seemed as if all the débris removed to cut out the canyon had been distributed at the mouth of the canyon and extended in

[1] Bull. Dept. Geol. Univ. Calif., Vol. I, Nos. 1, 4 and 8.

[2] The Geology of Carmelo Bay, Bull. Dept. Geol. Univ. Cal., Vol. I, No. 1.
The Post-Pliocene diastrophism of the Southern Coast of Calif., Bull. Dept. Geol. Univ. Cal., Vol. I, No. 8.

decreasing amount for two or three miles into the valley and to the right and to the left along the mountain side. This feature is beautifully shown on some of the United States Geological Survey topographic sheets[1] of southern California, where at the mouths of large canyons, such as the San Gabriel, instead of the contours running up towards the canyon, they circle around or away from it. Where the rainfall is somewhat greater the débris is carried further and distributed over a wider area, forming a fanlike extension of sediments. This feature has already been referred to in the discussion of the California Valley.

*Superimposed drainage.*—Near the head of Salinas Valley or immediately south of Santa Margarita, there is a valley from one to two miles wide underlaid by rather soft Tertiary sandstones and shales. To the east of the valley there is a granitic mountain range nearly 2000 feet high, while to the west there is a parallel range about 3000 feet high which is composed of rather soft Tertiary shales and sandstones. The Salinas River, instead of running through this valley, runs close by and parallel to it through a narrow deep canyon in the granitic mountain range. One stream in particular, and others to some degree, that run down from the western or sedimentary range of mountains, follow the valley for a few miles and then cut through the granitic hills by narrow canyons and flow into the Salinas River. The divides in the valley deflecting the streams are only about 100 feet[2] above the bed of the river while the narrow strip of granitic hills cut off between the river and valley, rises six and seven hundred feet above the river bed.

It seems most probable that in this case the soft sandstone and shales originally extended over the granitic mountains, as well as the valley and mountains to the west, and that the river was originally situated vertically over its present course, so that it has carved its way down through the soft covering and thence into the granite, and has so far kept below the more recent erosion-valley in the soft beds by its side.

[1] The Cucomonga and San Bernardino sheets of the U. S. Geol. Survey.

[2] See San Luis Obispo sheet U. S. Geol. surv. maps, surveyed in 1895.

EFFECTS OF VEGETATION ON TOPOGRAPHY.

*Sand dunes.*—During the summer of 1895 the writer assisted in mapping a number of sand dune areas along the coast in San Luis Obispo county. In all these areas there seemed to be no exception to the rule that where the sand was free from vegetation or obstruction, it was piled in ridges at right angles to the prevailing sea breezes, and that where patches of vegetation grew the dunes became parallel to the direction of the wind, and where the vegetation became thicker over the ground, the regularity of arrangement of the dunes was more broken. It seems that the change in direction of the dune ridges (from right angles to parallel with the winds where vegetation began), is due to the fact that vegetation once started would check the sand from moving at that point and make a shelter for deposits to the leeward. This point of the sand dune now being more stable, other plant growth would spring up, mainly on the leeward side, so as to lengthen and increase the elevation of the ridge while the unprotected sands at either side would drift away, thus forming narrow parallel ridges in the direction of the prevailing winds. Ridges fifty to seventy-five feet high and 400 to 600 feet long, or even longer, were not uncommon where the sand dunes are extensive.

*Hill slopes.*—While mapping over the area south of San Luis Obispo for some twenty or twenty-five miles, it was observed that the slope of the north side of the hills was steep while that of the south side was gentle. This proved to be almost invariably true, no matter in what direction the strata dipped or whether the underlying rock was loose sand.

This part of California, like most of the state, has a dry season and a wet one. During late spring, all summer, and early fall there is no rain and therefore any shelter from the sun's heat insures thicker and more permanent growth. So the north sides of the hills are more thickly covered with vegetation, especially perennial growths, and timber is often completely confined to them. The roots, leaves, and débris of the vegetation would protect the soil from washing away, while on the

south side of the hills the almost barren ground would lose much of its soil at every freshet. Over most of this area erosion is lowering the hill tops about as fast as stream corrasion lowers the creek beds. So the vertical distance between hill top and stream bed remains nearly the same, while the horizontal distance on the north side of the hill becomes less because the hill top recedes to the north as its south side is the principal one to be trimmed back by erosion. Such a process would in time almost produce a bluff. Such steep hill-sides may be seen immediately east of Arroyo Grande along the south side of Tar Springs Creek, San Luis Obispo county.

*Topography as modified by rainfall.*—In southeastern California where it is especially arid, there is almost no vegetation to hold the soil and disintegrated rock in place, so the weathered, loose, rock-fragments are soon blown to low ground leaving the rocks of the hillsides exposed in rough angular forms and the topographic outlines strongly fixed by the character of the rock mass or strata.

In the humid portion of the state, however, vegetation holds the soil from washing or drifting away and as the rocks continue to disintegrate, the hills are covered and rounded off by this mantle of soil and débris. Besides this reason for the rolling character of the topography, the following causes may be added: The sedimentary rocks as a rule are soft and much broken by numerous fissures, faults, and folds, so hard and fast lines or horizons to resist weathering do not often exist. The igneous rocks are usually great masses and necessarily show their characteristic rolling topography.

Taken as whole probably the most characteristic feature of the topography of the Pacific Coast is the rolling nature almost everywhere seen where relief is shown. This feature is especially impressive to one familiar with the bench, bluff, and flat topped mountain topography of the Mississippi valley region.

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# A COMPARATIVE STUDY OF THE LOWER CRETACEOUS FORMATIONS AND FAUNAS OF THE UNITED STATES.[1]

## INTRODUCTION.

BESIDES the facts of wide distribution and economic importance the Cretaceous is notable for the problems of more purely scientific nature than it presents. For example, near the middle of Cretaceous time or at the beginning of the neo-Cretaceous (to adopt William's term) there was a great transgression of the sea upon the land—perhaps the greatest and certainly one of the most clearly recorded extensive one in geologic history. During the Trias and Jura almost all the present area of the continent was above sea level, as is shown by the absence of marine strata of those periods, excepting in limited areas of the Rocky Mountain and Sierra Nevada regions. The advance of the sea commenced with the Cretaceous, covering nearly all of Mexico and extending northward in the United States to southern Kansas, besides encroaching on the coast range region in the West while the lower Cretaceous sediments were forming. Then there was a greater and more rapid advance until at its maximum extent the sea covered almost the entire area between the Mississippi River and the Wasatch range, extending northward to the Arctic Circle. It also washed the western slope of the Sierra Nevada and covered the entire coastal plain of the Atlantic and the Gulf. The advance was not continuous nor constant, however. There were retrograde movements so that locally fresh-water and brackish-water deposits with associated coal beds are interstratified with the marine formations. Before the close of the Cretaceous while the Laramie beds were being

[1] Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Columbian University, Washington, D. C., June 1897.

laid down the sea had retreated from most of the continental area and it has never since invaded it beyond the coastal border regions. It is a noteworthy fact, as Neumayr[1] and others have pointed out, that there was a similar invasion of the sea upon the other continents in mid-Cretaceous time.

The occurrence of contemporary marine, fresh-water and brackish-water formations has greatly complicated the classification and correlation of the Cretaceous beds. Deposits formed under such diverse conditions naturally have few features in common, either lithologically or paleontologically, and their correlation must usually depend on similarity of stratigraphic and structural relations with formations of known age. In a few cases, however, the same flora and other land organisms have been preserved in both marine and fresh-water beds, and have thus demonstrated their practical contemporaneity.

Besides the sharp contrasts between marine and non-marine beds there are several distinct facies within the marine Cretaceous formations. Whether the paleontological differences are due to climate, to isolation, to differences in depth or in the nature of the sea bottom, are questions that should be solved independently in each case, but their solution is usually difficult. The first essential is to determine that the formations compared are actually contemporaneous or homotaxial. A failure to do this has led to serious errors in the past. For example, Roemer[2] noticed that the Cretaceous fauna of New Jersey is very different from that found in Texas in beds that he supposed to be contemporaneous. He also noticed that the former corresponded rather closely with the Cretaceous fauna of northwestern Germany, while the Texan fauna found its nearest analogues in the Cretaceous of southern Europe bordering on the Mediterranean. He concluded, therefore, from these geographic relations that the faunal differences were due mainly to climate, that the present climatal zones were already established in Cretaceous time and even that the ocean currents had

[1] Erdgeschichte, Bd. 2, p. 377.

[2] Am. Jour., Sci. 2d. ser., Vol. II, 1846, p. 364. Kreideb. v. Texas, 1852, p. 25.

approximately their present positions, since the European localities are respectively several degrees farther north than their American analogues, corresponding to the position of isothermal lines on opposite sides of the Atlantic at the present time. This was one of the first attempts to establish climatal zones at such an early period, as it was published even before von Buch's[1] generalization that the absence of Cretaceous faunas in the polar regions is due to the climatic conditions of that period. In Neumayr's studies of Mesozoic climates use was made of the difference between the Cretaceous faunas of New Jersey and Texas, and it has recently been cited by Kayser[2] and by J. Perrin Smith.[3] There is some evidence of the existence of climatal zones in the Cretaceous and even earlier in Mesozoic time, but Roemer's original examples should no longer be cited as proof, for it is now known that the faunas Roemer compared were not contemporaneous, the base of the marine Cretaceous beds in New Jersey being somewhat newer than the uppermost horizon that furnished the fossils he described from Texas. If he had made his comparisons with the Ripley fauna, which occurs near the top of the Texan Cretaceous and only a few miles east of the beds studied by him, Roemer's conclusion would probably have been very different, for a very large percentage of the species are identical with the New Jersey forms, and there is nothing suggestive of a warmer climate.[4] The Upper Cretaceous faunas of the Atlantic and Gulf border regions, when comparison is made with strictly homotaxial zones, are remarkably uniform along the whole coast from Texas to New Jersey.

The correlated faunas of the Rocky Mountain region and the great Plains show much greater differences when compared with the faunas just mentioned, and these may reasonably be

[1] Verbreitung und Grenzen d. Kreidebildungen. Verhandl. des Naturhist. Vereins d. Preuss. Rheinlande u. Westphalien, Bd. 7, pp. 211–242.

[2] Text-book of Comparative Geology, translated by Lake, p. 283, Lond., 1893.

[3] Jour. of Geol., Vol. III, p. 485, Chicago, 1895.

[4] See Whitfield; Bull. Am. Mus. Nat. Hist., Vol. II, 1889, pp. 113–116 and White, Bull. U. S. Geol. Surv., No. 82, pp. 84, 111.

attributed in part to the influence of climate, but it would carry us too far from our subject to discuss this question fully.

The life of the Cretaceous period offers many other points of general interest, chief among which is the fact that while it is essentially Mesozoic in character, and is thus allied with the life of earlier periods, it nevertheless includes the earliest recorded repres ntatives of very many recent generic and family types and some groups of higher rank, and in the later stages this modern element is often relatively large. This statement refers chiefly to plants and invertebrates, for, with the exception of the Teleost fishes, which are introduced for the first time, the vertebrates nearly all belong to types now extinct or of relatively little importance. So far as the record goes the great group of placental mammals was not yet introduced, and the vertebrate fauna consists largely of Mesozoic types of reptiles, such as dinosaurs, pterosaurs and pythonomorphs, with a few small mammals of the lowest groups, and birds of archaic types.

Among the invertebrates the Ammonoidea are very greatly differentiated and finally become extinct with the close of the period. Many other forms, such as Inoceramus, certain types of Ostreidae, Nerinea, Anchura, Pugnellus, etc., do not pass the upper limits of the Cretaceous. On the other hand, the Ostreidae, Anomiidae, Mytilidae, Unionidae, Veneridae, Mactridae, Turritellidae, Naticidae, Volutidae, etc., are represented by forms closely related to living species. The flora is completely revolutionized and modernized during the Cretaceous. Early in the Cretaceous the first Dicotyledons occur and by mid-Cretaceous time they largely predominate and numerous genera of trees that time still live in our forests are already introduced, so that the biologist who is studying recent species must often go back to the Cretaceous faunas and floras to complete his data for a rational classification.

### RECOGNITION OF THE LOWER CRETACEOUS IN THE UNITED STATES.

Before going farther it may be well to recall the general classification of Cretaceous deposits as adopted in Europe. It is

now customary to recognize only two principal divisions — Lower Cretaceous and Upper Cretaceous — instead of three as formerly. The number and nomenclature of the subdivisions varies in different countries and with different authors, but the terms Neocomian, Urgonian, Aptian, Albian, Cenomanian, Turonian, Senonian and Danian proposed by d'Orbigny are frequently used and universally understood.

In Neumayr's *Erdgeschichte*[1] the following arrangement is adopted:

| Upper Cretaceous. | Lower Cretaceous. |
|---|---|
| Senonian. | Gault. |
| Turonian. | Aptian. |
| Cenomanian. | Neocomian. |

In this classification of the Lower Cretaceous the Wealden is treated as simply a non-marine facies of the Neocomian, the Urgonian is made a subdivision of the Neocomian (as it was by d'Orbigny also) and the English name Gault is substituted for Albian. Some authors place the Gault in the Upper Cretaceous, but for comparison with American formations it is more satisfactory to classify it with the older beds.

These minor subdivisions are not applicable to the American Cretaceous excepting in the most general way, and, as Dr. White has insisted, it is not probable even that the corresponding principal divisions as recognized on the two continents are strictly homotaxial, but the accumulating evidence tends to show that the difference is not very great. In making an independent and natural classification of our formations we have perhaps placed a few beds in the Lower Cretaceous that by European standards would go in the Upper Cretaceous.

The first definite recognition of Lower Cretaceous in this country based on good evidence was by Professor Jules Marcou,[2] who in 1855 identified a number of fossils from Texas as Neocomian, and asserted that rocks of that age cover considerable

[1] Bd. 2, p. 344.

[2] Pacific R. R. Reports, 8vo edition, Vol. IV, pp. 40–48, 1855; republished in 4to edition and in Geology of North America.

areas in Texas and Indian territory. Marcou has maintained the correctness of his determination in numerous subsequent papers, but for various reasons his opinion, though essentially correct, did not meet with general acceptance for many years. The principal causes that conspired to prolong this misconception were (1) Marcou's own error in referring to the Jurassic certain New Mexican exposures of a part of the same series; (2) Roemer's previously published important work, "Die Kriedebildungen von Texas," in which on paleontological grounds all the Texan Cretaceous beds were referred to the Upper Cretaceous;[1] (3) the publication of Shumard's[2] section in which the stratigraphic succession is very erroneously given, and (4) the fact that the investigation of other regions in the United States did not reveal any Lower Cretaceous beds that were really comparable with those of Texas. The subject remained thus until 1887 when the publication of papers by Dr. C. A. White[3] and Mr. R. T. Hill,[4] based on the latter's field work, established the fact that there is in Texas a great series of Cretaceous rocks underlying the generally recognized Upper Cretaceous of other parts of the country. This is the Comanche series that has since become so familiar through the numerous papers of Mr. Hill.

[1] The idea has been current for some years that ROEMER'S principal error was a stratigraphic one in placing his "Cretaceous of the Highlands" above the "Cretaceous at the foot of the Highlands" as he did tentatively in his earlier work "Texas," but a careful perusal of the introductory pages — especially page 19 — of the "Kreibildungen" will show that he did not finally attempt to establish any stratigraphic succession, and that he admitted that there were both paleontologic and physical reasons for regarding the beds of the Highlands as older than the others, and he suggested that their topographically higher position might have been caused by a fault. His real error was that in his paleontological comparisons with the Cretaceous of southern Europe, he did not recognize the now well-known fact that there are two distinct horizons, one in the Upper Cretaceous and the other in the Lower, each characterized by peculiar species of Rudistae, Chamidae, etc.

[2] Trans. Acad. Sci., St. Louis, Vol. I, pp. 582–589, 1856–1860.

[3] On the Cretaceous formations of Texas and their relations to those of other parts of North America. Proc. Phila. Acad. Nat. Sci., 1887, pp. 39–47.

[4] The topography and geology of the Cross Timbers and surrounding regions in northern Texas. Am. Jour. Sci., 3d ser., Vol. XXXIII, pp. 291–303, pl. 6. The Texas section of the American Cretaceous. Am. Jour. Sci., 3d ser., Vol. XXXIV, 1887, pp. 287–319.

Some years before the investigation of the Texan Cretaceous was begun several geologists described strata in Virginia, Maryland, Delaware, and New Jersey that are now usually referred to the Potomac formation, but they had few facts on which to base their age determination. Thus W. B. Rogers[1] described these beds as Upper Secondary, and provisionally referred them to the Upper Jurassic, though he later[2] suggested that they might form a "passage-group analogous to the Wealden of British geology." Tyson[3] also described a part of the same series under the designation of "iron ore clays" which he at first referred to the Cretaceous, but afterward[4] placed "at least as low as the Oolitic." According to Dawson[5] and Fontaine[6] Tyson considered that these beds belonged to the Wealden, but he seems not to have published that opinion. In 1886 Mr. W J McGee[7] named and described the Potomac as a distinct formation including the above mentioned beds that had been discussed by Rogers and Tyson. Its determination as of Lower Cretaceous age has been mainly due to the paleobotanical work of Professors L. F. Ward[8] and W. M. Fontaine.[9]

In 1869 Gabb and Whitney[10] defined the Shasta group of California, stating that "It contains fossils seemingly representing ages from the Gault to the Neocomian, inclusive." The Shasta group has ever since been referred to the Lower Cretaceous, and subsequent investigations have only confirmed the

[1] Report of Prog. of Geol. Surv. of Va. for 1840, Richmond, 1841. Idem for 1841, Richmond, 1842. Both reprinted in Geology of the Virginias, 1884, pp. 413–546.

[2] Proc. Bost. Soc. Nat. Hist., Vol. XVIII, 1875, p. 105.

[3] First Rept. State Agricultural Chemist of Md., pp. 41–43, Annapolis, 1860.

[4] Second Rept. State. Agri. Chemist, p. 54, Annapolis, 1862.

[5] Trans. Roy. Soc. Canada, Vol. III, 1885, sec. 4, p. 18.

[6] Monograph U. S. Geol. Surv., No. 15, p. 5.

[7] Rept. of Health Officer for the Dist. of Columbia for 1885, pp. 23–25; Am. Jour. Sci., 3d ser., Vol. XXXV, 1888, pp. 120–143.

[8] Am. Jour. Sci., 3d ser., Vol. XXXVI, 1888, pp. 119–131.

[9] Monograph 15, U. S. Geol. Surv., 1889. See also many subsequent articles by both authors and by McGee, Darton, White, Marsh, and Clark listed in the accompany bibliography.

[10] Palæont. of California, Vol. II, p. xiv.

original suggestion as to its age. The stratigraphy and paleontology of the Shasta beds have been described or discussed by Gabb, Becker, White, Diller, Turner, Fairbanks, and Stanton.

Soon after the definition of the Shasta, Richardson[1] described strata in the Queen Charlotte Islands that were recognized by Billings from the invertebrate fossils as in part the equivalent of the Shasta, and on the evidence of a few plants were assigned to either the Jurassic or the Lower Cretaceous by Dawson. The fauna of these beds and of their equivalents on the mainland of British Columbia has since been described by Whiteaves, who regards them as not later than the Gault.

A few years later a series of fresh-water coal-bearing beds, the Kootanie formation, in the Rocky Mountain region of southern Canada, was recognized and defined by Dr. Geo. M. Dawson. The accompanying flora was studied by Sir William Dawson, who determined its age to be Lower Cretaceous and published the first account[2] of the formation in connection with the description of the flora. In 1887, the coal-bearing rocks of Great Falls, Mont., were referred to the Kootanie by Professor J. S. Newberry,[3] who later discussed the flora more fully and pointed out its close relationship with the flora of the Potomac. The possible occurrence of beds of the same age in the Black Hills, South Dakota, has been shown by Professor L. F. Ward[4] on the evidence of cycads and a few other plants of Lower Cretaceous aspect in beds that have formerly been referred to the Dakota.

Before this time and soon after the Potomac formation became known, Smith and Johnson[5] had described the Tuscaloosa formation in Alabama. It is now correlated with the upper portion of the Potomac or the Raritan beds.

[1] Geol. Surv. of Canada, Rept. of Progress for 1872–3, pp. 32–65.

[2] Science, Vol. V, 1885, p. 31; Trans. Roy. Soc. Canada, Vol. III, 1885, sec. 4, pp. 1–22; idem, Vol. X, 1892, sec. 4, pp. 79–93.

[3] School of Mines Quarterly, Vol. VIII, 1887, pp. 327–330; Am. Jour. Sci., 3d ser., Vol. XLI, 1891, pp. 191–201.

[4] Jour. Geol., Vol. II, 1894, pp. 250–266.

[5] Bull. U. S. Geol. Surv., No. 43, 1887, p. 95.

From this review it is seen that the Lower Cretaceous formations now known in the United States are the Comanche series of the Texan region, the Shasta group (including Knoxville and Horsetown beds) of the Pacific Coast, the Kootanie of Montana and possibly of the Black Hills, the Potomac of the Atlantic coastal plain, and the Tuscaloosa of the Gulf border. Only the first two are marine formations. In our comparisons of these formations it will not be necessary to enter into minute details of stratigraphy and lithology, since the most general descriptions will show that in most cases we have to deal with contrasts rather than with resemblances. This is true not only when the marine beds are compared with the non-marine, but also when the two marine formations are compared with each other, or the Potomac is compared with the Kootanie. In the descriptions that follow, mainly summarized from the latest published accounts, the principal characteristics of each formation are given, beginning with the fresh-water beds. The statements concerning the invertebrate faunas embody more of the results of my own studies.

GEOLOGIC DESCRIPTION OF THE FORMATIONS.

*The Potomac formation.*—This term was originally applied by McGee to certain non-marine beds in Maryland, the District of Columbia, and Virginia, resting against the old crystalline rocks of the Piedmont region, and unconformably overlain by marine Upper Cretaceous deposits. The Potomac as thus defined is composed of irregular deposits of variegated clays, sand, arkose, pebbles, and bowlders, with local lenses of iron ore and lignitic seams. The sand and arkose are sometimes indurated, but frequently are unconsolidated deposits. In general, the arenaceous deposits seem to predominate in the lower part of the series and argillaceous beds in the upper, though no single stratum retains the same lithologic character over any considerable area. The estimates of thickness vary from 500 or 600 feet (McGee) to 1175 feet (Ward). Professor Ward,[1] who has

[1] See 15th Ann. Rept. U. S. Geol. Surv., pp. 313–397, and 16th idem, pp. 469–540.

studied the stratigraphy and the flora of the Potomac in great detail, retains under that name all the strata originally included in it, and also makes it comprise all the beds that have been named the Raritan formation, extending from Maryland across Delaware and New Jersey to the islands off the southern coast of New England. That is, he makes it coextensive with Dr. White's[1] non-marine division of the Cretaceous of the Atlantic border region which was believed to consist of two distinct formations, separated by a time interval that marked the distinction between Lower and Upper Cretaceous. Though assigning these beds all to a single formation Professor Ward recognizes in it six distinct "series," as follows:

Potomac
6. Albirupean [in part equivalent to Raritan].
5. Iron Ore,
4. Aquia Creek,
3. Mount Vernon,
2. Rappahannock,
1. James River.

Each of these divisions, excepting No. 5, is, according to the author cited, characterized by a distinct florula altogether constituting a flora of from 800 to 1000 species. Detailed discussions and comparisons of this flora are contained in the articles above referred to in the fifteenth and sixteenth annual reports of the U. S. Geol. Survey. From these it appears that while the whole formation is referred to the Lower Cretaceous the flora of the lower beds, in which the earliest known dicotyledons appear, has Jurassic affinities, and is related to the Wealden flora. There is a progressive change, the modern types predominating more and more until in the uppermost beds (No. 6) the plants show a marked affinity to the Upper Cretaceous Cenomanian flora. An interesting comparison of the Potomac flora with the Lower Cretaceous flora of Portugal, shows that while they have but few species in common the general characters of the two floras are very similar, and as Professor Ward remarks, "the lower Cretaceous flora of Portugal is, botanically speaking, a very close repetition of that of America." This fact is in interesting agreement

[1] Bull. U. S. Geol. Surv., No. 82, pp. 74–100.

with other independent sources of evidence, for the Portuguese plant beds are interstratified with strata carrying marine faunas that are, as we shall see, closely related to the fauna of the Comanche series, and one of the lower horizons in the Comanche has yielded fossil plants closely connected with the flora of the lower Potomac.

Invertebrate fossils are remarkably scarce in the Potomac, and the few that have been found do not afford any definite evidence as to the age of the beds. The only mollusks known from the lower horizons developed in Maryland and Virginia, are a few internal casts apparently belonging to small simple forms of Unio, whose only geological value is to show the fresh-water origin of the beds. In New Jersey, besides some Unios that probably came from a much later formation, five species of mollusks have been reported from the Raritan formation.[1] They have been referred to Astarte, Corbicula, Gnathodon, and Ambonicardia (gen. nov.), but not one of them is well enough preserved to show generic characters, and in invertebrate paleontology, at least, age determinations, based on new species of doubtful genera, are worthless.

Vertebrate fossils have been collected from the Lower Potomac in a limited area between Washington and Baltimore. One species based on a tooth, *Astrodon Johnsoni*, has been described by Dr. Leidy, and Professor Marsh[2] has named five others: *Pleurocoelus nanus*, *P. altus*, *Priconodon crassus*, *Allosaurus medius*, and *Coelurus medius*. He states that associated with these there are remains of crocodiles and tortoises, of Jurassic types, some fishes and a few mollusks. Also that "The fossils here described, and others from the same horizon seem to prove conclusively that the Potomac formation in its typical localities in Maryland is of Jurassic age and lacustrine origin." The genera Allosaurus and Coelurus were originally described from the Atlantosaurus beds (Jurassic) of the Rocky Mountain region, and Pleurocoelus has since been found in the same beds repre-

[1] Monograph 9, U. S. Geol. Surv., pp. 22–28.

[2] Am. Jour. Sci., 3d. ser. Vol. XXXV, 1888, pp. 89–94.

sented by a Potomac species. According to Lydekker Pleurocoelus also occurs in the Wealden of England. In recent papers Professor Marsh[1] has attempted to establish the Jurassic age of the whole Potomac formation in its broadest sense. He correlates it by the relationship of the vertebrate faunas on the one hand with the Atlantosaurus beds, and on the other with the European Wealden, asserting that they are homotaxial equivalents. Assuming that the Atlantosaurus beds are Jurassic, it consequently follows, according to his reasoning, that the Wealden and the Potomac are also Jurassic. But even admitting that the vertebrate faunas are so closely related as to establish the equivalence of the deposits in these three widely separated regions, the correlation can apply only to the beds in which the fossils occur, and in the Potomac they have so far been found only in the lower portion. Recent stratigraphic studies by Professor W. B. Clark and Mr. Arthur Bibbins on the Potomac in Maryland, have an important bearing on this question. A preliminary statement of their results, including a new classification of the deposits, was published[2] some months ago, and a more detailed account has been issued since the present paper was first written.[3] Their most important results are summarized as follows:

"It is the conclusion of the authors, founded upon a detailed stratigraphic study of the Potomac group, that all the beds which have afforded dicotyledonous types of plant life are above those from which Professor Marsh has obtained vertebrate remains, and moreover, that a marked unconformity exists between the two series of deposits. . . . .

"The several formations into which the larger unit of the Potomac group has been divided, are as follows:

[1] Am. Jour. Sci., 4th ser., Vol. II, 1896, pp. 295–298, 375–377, 433–447. See also articles on the same subject by HOLLICK, WARD, HILL, and GILBERT, Science, Vols. IV and V, 1896, 1897.

[2] Physical Features of Maryland; Maryland Geol. Surv., Vol. I, Pt. 3, pp. 56–59, April 1897.

[3] JOUR. GEOL., Vol. V, pp. 479–506, July–Aug. 1897.

| | | |
|---|---|---|
| Lower Cretaceous | Raritan Formation | Potomac. |
| | Patapsco " | |
| Upper Jurassic (?) | Arundel " | Group" |
| | Patuxent " | |

According to these authors all of the Potomac vertebrates that have been recorded have come from the Arundel formation, while practically the whole of the Potomac flora occurs in higher horizons above the principal unconformity which separates the Patapsco from the Arundel. All of Professor Ward's plant-bearing "series" below the Albirupean are believed to be local subdivisions and variations of the Patapsco formation. The underlying beds are doubtfully assigned to the Upper Jurassic on the authority of Professor Marsh's determination of the affinities of the vertebrates. It has been shown, however, that his comparisons are chiefly with the Wealden fauna, and if the difficult stratigraphy of the Potomac has now been correctly determined the evidence tends to prove the post-Wealden age of the principal plant-bearing horizons.

There have long been differences of opinion as to the age of the Wealden, and it may well be that it is partly Jurassic, but its constantly close association with the Cretaceous, and the fact that where it is present the lowest marine beds of the Neocomian are always absent, are strong arguments for regarding it as a non-marine facies of the Neocomian. If all the Wealden deposits are transferred from the Cretaceous to the Jurassic because the dinosaurs are closely related to those of the Jurassic, then we know practically nothing of the land fauna of the Lower Cretaceous, and no one can say whether the dinosaurs that must have lived in early Cretaceous time, were very different from those of the Jurassic or not. Professor Marsh's statements may be fairly interpreted to mean that the age of the Atlantosaurus beds is dependent on that of the Wealden, and if the latter is Cretaceous the former are also. There is nothing in the stratigraphic relations of the Atlantosaurus beds that would prevent their reference to the Lower Cretaceous, for they are everywhere immediately overlain by Upper Cretaceous strata.[6] How-

[6] There is a possible exception to this in the Black Hills of South Dakota, where

ever these questions may be finally decided, it is evident that the discussion as to the Potomac formation is not so much on its correlation with deposits elsewhere as on the more general question of the upper limits of the Jurassic.

*The Tuscaloosa formation.*—The beds known under this name have their principal development in Alabama, extending thence eastward into Georgia and westward into Mississippi. According to Prof. E. A. Smith[1] the formation consists of "heavy bedded purple and mottled and gray clays in the lower parts, alternating with more distinctly stratified clays containing an abundance of plant remains, chiefly in the form of leaf impressions. Above these clayey beds are sands of various colors, white, yellow, gray, pink, and purple, usually micaceous and strongly cross-bedded. In many places irregular pockets of small angular chert pebbles are interbedded with the sands, but these pebble beds make only a very small proportion of the strata. In places also beds of dark red and mottled clay occur in the upper part of the formation." In the eastern part of the area it rests on ancient crystalline rocks while farther west it laps up on the Paleozoic sediments. The overlying beds are of Upper Cretaceous age.

The thickness of the Tuscaloosa is estimated at 1000 feet.

Lithologically and stratigraphically the Tuscaloosa is seen to correspond closely with the Potomac and the evidence of the flora leads to the same correlation. Professor Smith[2] publishes a list of 35 species of fossil plants determined by Professor Ward, who compares them with the Amboy Clay (*i. e.* Uppermost Potomac) flora. In later publications Professor Ward[3] definitely correlates the Tuscaloosa with the Amboy and Raritan clays, suggesting that possibly one of the older horizons of the Potomac may also be represented in Alabama. No animal remains

Professor Ward obtained plants that he regards as Lower Cretaceous, and the Atlantosaurus fauna has also been found in this same region, but what relation the plant-beds have to the vertebrate horizon, and whether the plants and vertebrates do not really occur in the same bed has not been determined.

[1] Rep. on Geol. of the Coastal Plain of Ala., pp. 307–308, Montgomery, 1894.

[2] *Ibid.*, p. 348.

[3] 15th Ann. Rept. U. S. Geol. Surv., pp. 337–338; 16th Ann. Rept., p. 470.

have been reported from these southern beds. According to Mr. N. H. Darton[1] the Potomac deposits are practically continuous along the whole Atlantic coastal plain until they connect with the Tuscaloosa. It is evident that conditions of deposition were remarkably uniform throughout this long coastal border region during Potomac time but the earlier part of the epoch is recorded by deposits now visible only in the middle portion of the area. The northern and southern ends either did not receive deposits until towards the close of the epoch or else the early deposits were overlapped and concealed by the later beds.

*The Kootanie formation.*— A somewhat detailed description of the typical area of the Kootanie is given by Dr. Geo. M. Dawson.[2] It is found in the Rocky Mountains of Canada between latitudes 49° and 51° 30′. The beds there have a total estimated thickness of over 7000 feet and consist chiefly of shales and sandstones of very varied texture and appearance, with beds of coal. The Canadian localities have yielded a flora[3] of about 27 species which show by identical and allied species a very close relationship with the Potomac. No animal remains have been reported excepting one imperfect specimen of a Goniobasis indicating fresh waters, and a fragment of a belemnite which was very probably derived from an older formation.

In the United States the Kootanie occurs at Great Falls, Montana, near which place a thick coal bed in the formation is mined. The section has been described by Mr. W. H. Weed[4] who states that the Kootanie "is a series of rapidly alternating sandstones and clay shales with few and thin beds of impure limestone. Individual beds are inconstant, the heavy ledges of heavy sandstone passing laterally into arenaceous clays and *vice versa*."

The top of the formation is not clearly defined but the thickness is evidently several hundred feet. About 38 species of fossil

[1] Bull. Geol., Soc. Am., Vol. VII, 1896, pp. 514–517.

[2] Rept. Geol. Surv. of Canada for 1885, Rept. B. A more general account in Am. Jour. Sci., 3d ser., Vol. XXXVIII, pp. 120–127.

[3] Trans. Roy. Soc. Canada, Vol. III, 1885, Sec. 4, pp. 1–10. Idem, Vol. X, 1892, Sec. 4, pp. 79–93. Idem, Vol. XI, 1893, Sec. 4, p. 11.

[4] Two Montana coal fields. Bull. Geol. Soc. Am., Vol. III, 1892, pp. 301–323.

plants have been listed or described from the Kootanie of this neighborhood by Professors Newberry[1] and Fontaine.[2] These show a close connection with the not distant Canadian Kootanie, and more than half of them (21 out of 38) have also been identified from the Potomac. It is noteworthy, however, that no dicotyledons have been found in the Kootanie, thus indicating that the higher horizons of the Potomac are possibly not represented there. Invertebrates are represented in the Great Falls area only by a few imperfect specimens of Unio. A higher bed which may belong to a later formation has yielded undescribed species of Neritina, Goniobasis, and Corbula (?).

It is evident that the Kootanie and Potomac were laid down in distinct basins of fresh and brackish waters and that the floras prove that they are in part homotaxial equivalents.

*The Shasta group.*— This general name was given by Gabb and Whitney to all the Lower Cretaceous rocks of California. In 1885 Dr. C. A. White[3] and Dr. G. F. Becker[4] named two subdivisions of the Shasta, the Knoxville and the Horsetown beds, that have since been generally recognized. Detailed sections have been described by Turner,[4] Diller[5] and the present writer[6] who has recently reviewed the geology of the Knoxville beds and described their fauna.

The Shasta is a marine formation distributed along the western side of the Sacramento valley and in the coast ranges of California, Oregon, and Washington. The lower divisions have been recognized as far north as latitude 35°.

"Dark clay shales greatly predominate over all other kinds of rocks in the Knoxville beds, but there is also considerable sandstone, usually in thin beds. In some places the lower part of the formation consists of alternations of shale and sandstone,

[1] Am. Jour. Sci., 3d ser., Vol. XLI, 1891, pp. 191–201.

[2] Proc. U. S. Nat. Museum, Vol. XV, 1892, pp. 487–495.

[3] Bull. U. S. Geol. Surv., Nos. 15 and 19.

[4] Bull. Geol. Soc. Am., Vol. II, 1891, pp. 303–314.

[5] Am. Jour. Sci., 3d ser., Vol. XL, 1890, pp. 476–478. Bull. Geol. Soc. Am., Vol. IV, 1893, pp. 205–224. Idem, Vol. V, pp. 435–464.

[6] Bull. U. S. Geol. Surv., No. 133, 1896.

or calcareous material, in bands only a few inches thick. There are also occasional thicker bands of sandstone, and sometimes massive conglomerates. The larger bodies of shale frequently contain many calcareous concretions, and such concretions are sometimes found even in the coarse conglomerates. More rarely there are larger bodies of limestone, several feet in thickness, but they do not form continuous beds of any great extent. The conglomerates also appear to be local deposits of no great length, though sometimes of very considerable thickness." The overlying Horsetown beds have essentially the same lithologic character and are distinguished mainly by marked differences in the fauna—especially by the absence of Aucella and the greater abundance and variety of the ammonites. Where the base of the Shasta has been observed it rests on metamorphic rocks of undetermined age. It is conformably overlain by the upper Cretaceous Chico formation which in its basal portion is probably as old as the Cenomanian.

The Lower Cretaceous has an enormous thickness at some localities on the Pacific coast. A section on Elder Creek, Tehama county, Cal., measured by Mr. Diller, showed about 20,000 feet of Knoxville and 6000 feet of Horsetown beds without any evidence of duplication of strata. This thickness is exceptional, though other localities in the same region show apparent thicknesses of 12,000 to 15,000 feet.

Although the Shasta group is of marine origin it has yielded a number of land plants from several different horizons ranging from the upper third of the Knoxville to near the top of the Horsetown beds. Professor Fontaine has recognized twenty-six different forms among them. He says that "all have their nearest relations in Lower Cretaceous forms, and there is no plant that would indicate an age different from Lower Cretaceous." A large proportion of the species occur in the Potomac and a few are found in the Kootanie and in the Comanche series, none of which offers any other means of direct comparison with the Shasta. Here, as in the Kootanie, no dicotyledons have been found.

In my recent work on the Knoxville fauna the following species are described:

Rhynchonella schucherti S.
R. whitneyi Gabb
Rhynchonella sp.
Terebratula sp.
Terebratula californica S.
Ostrea sp.
Anomia senescens S.
Spondylus fragilis S.
Lima multilineata S.
Pecten californicus Gabb?
Pecten sp.
Pecten complexicosta Gabb
Avicula whiteavesi S.
Aucella piochii Gabb
A. piochii var. ovata S.
A. crassicollis Keyserling
Inoceramus ovatus S.
Modiola major Gabb
Myoconcha americana S.
Pinna sp.
Arca textrina S.
Pectunculus? ovatus S.
Nucula gabbi S.
Nucula storrsi S.
Leda glabra S.
Cardiniopsis unioides S.
Solemya occidentalis S.
Astarte corrugata S.
Astarte californica S.
Astarte trapezoidalis S.
Opis californica S.
Lucina ovalis S.
L. colusaensis S.
Cyprina occidentalis Whiteaves
Solecurtus? dubius S.
Corbula? persulcata S.
Corbula filosa S.
Dentalium californicum S.
Helcion granulatus S.
Fissurella bipunctata S.
Pleurotomaria sp.
Turbo paskentaensis S.
T. wilburensis S.
T. trilineatus S.
T. colusaensis S.
T. morganensis S.
T.? humerosus S.
Amberleya dilleri S.
Atresius liratus Gabb
Turritella sp.
Hypsipleura? occidentalis S.
Hypsipleura gregaria S.
Cerithium paskentaensis S.
C. strigosum S.
Cerithium sp.
Aporrhais sp.
Phylloceras knoxvillense S.
Lytoceras batesi (Trask)
Desmoceras californicum S.
Desmoceras sp.
Olcostephanus mutabilis S.
O. trichotomus S.
Hoplites hyatti S.
H. storrsi S.
H. angulatus S.
H. crassiplicatus S.
H. dilleri S.
Perisphinctes sp.
Diptychoceras? sp.
Crioceras latus Gabb
Aptychus? knoxvillensis S.
Belemnites impressus Gabb
Belemites tehamaensis S.
Belemites sp.

To quote again from my previous paper: "When studying the Knoxville fauna as a whole, either in the field or from aver-

age collections, one is impressed with the excessive preponderance of the Aucellæ, so far as number of individuals is concerned. In many places they are so abundant that they must have actually monopolized the sea bottom, crowding out everything else.

"Considering the fauna as an assemblage of species, the proportion of brachiopoda, though there are so few, is somewhat greater than in other American Cretaceous faunas. Among the mollusca the variety of forms of Turbinidæ is noteworthy. The proportion of ammonoids is also quite large, and there is an unusual development of the genus Hoplites."

The Aucellæ do not pass above the Knoxville, or to speak more accurately, the top of the Knoxville is drawn at the upper limit of the Aucella beds. Several other Knoxville species, however, do pass up into the succeeding Horsetown fauna. This fauna has not yet been revised and a considerable number of undescribed species are known in recent collections, but the following lists, though incomplete, will give a correct idea of its general character. In the lower part of the Horsetown ammonites are locally very abundant, the genera Lytoceras and Phylloceras being especially well represented in individuals. The following species occur in this portion of the series:

Pentacrinus sp.
Rhynchonella sp.
Pecten operculiformis Gabb
Plicatula variata Gabb
Avicula whiteavesi Stanton
Inoceramus sp.
Nemodon vancouverensis (Meek)
Trigonia æquicostata Gabb
Trigonia leana Gabb?
Opis sp.
Eriphyla sp.
Protocardia sp.
Pleuromya papyracea Gabb
Lunatia avellana Gabb
Potamides diadema Gabb
Helicaulax? bicarinata Gabb
Actæon impressus Gabb
Lytoceras batesi (Trask)
Phylloceras onoense Stanton
Hoplites remondi (Gabb)
Olcostephanus traski (Gabb)
Desmoceras hoffmanni (Gabb)
Crioceras latus Gabb
Crioceras percostatus Gabb
Ancyloceras remondi Gabb
Helicancyclus æquicostatus Gabb
Diptychoceras lævis Gabb
Belemnites impressus Gabb

The few fossils that have been collected from the middle portion of the Horsetown do not show any decided change in

the fauna until the extreme upper beds are reached, when a more abundant fauna appears that shows a blending with the succeeding Upper Cretaceous Chico fauna. These upper Horsetown beds have yielded the following species:

Rhynchonella sp.
Exogyra parasitica Gabb
Pecten operculiformis Gabb
Mytilus quadratus Gabb
Mytilus cf. lanceolatus Sowerby
Cucullæa truncata Gabb
Nemodon vancouverensis (Meek)
Leda translucida Gabb
Trigonia æquicostata Gabb
Trigonia leana Gabb
Meekia sella Gabb
Meekia navis Gabb
Meekia radiata Gabb
Chione varians Gabb
Tellina matthewsonii Gabb
Mactra sp.
Pleuromya papyracea Gabb
Panopæa concentrica Gabb
Lunatia avellana Gabb
Liocium punctatum Gabb
Actæonina californica Gabb
Ringicula varia Gabb
Desmoceras hoffmanni (Gabb)
Desmoceras cf. beudanti (Brongniart)
Haploceras breweri (Gabb)
Lytoceras sacya Forbes
Schloenbachia inflata (Sowerby)
Acanthoceras cf. mammillare (Schloth.)
Belemnites sp.

After weighing the available paleontologic evidence and making all practicable comparisons with foreign Mesozoic fossils the conclusion was reached that the whole of the Knoxville is referable to the Neocomian and that the Horsetown includes all the rest of the Lower Cretaceous and possibly extends up into the Upper Cretaceous.

The abundance of Aucellæ gives the Knoxville fauna a decided boreal appearance, for the distribution of that genus has been considered essentially circumpolar. Some of the ammonitic types also point in the same direction, but the genera Lytoceras and Phylloceras are also represented, and these are the genera that Neumayr considered especially characteristic of the southern or tropical zone. With the disappearance of Aucella the fauna of the Horsetown becomes almost purely southern in type, so far as the ammonites are concerned, as Professor J. P. Smith[1] has stated; but this change can hardly be attributed to a change in climate, for it will be remembered that Aucella beds occur as

[1] Mesozoic Changes in the Faunal Geography of California, JOUR. GEOL., Vol. III, 1895, pp. 381–382.

far south as the Himalayas in India and almost to the tropics in Mexico. Besides, the fossil plants of both divisions of the Shasta, as well as those of the more northern Kootanie, indicate at least a warm temperate climate.[1] The facts seem to support Dr. Kossmat's[2] opinion that Neumayr exaggerated the influence of climate on the distribution of ammonites [and other Mesozoic invertebrates as well], and that the climatic influence was of little importance when compared with geographic relations, the presence or absence of opportunities for free communication, etc. Neumayr[3] himself referred the California Cretaceous to his Indo-Pacific region, and spoke of the persistent conservative character of the Mesozoic faunas of that region. The earliest Cretaceous deposits are apparently not preserved on the Asiatic side of the Pacific, but beginning with the Upper Cretaceous beds, usually classed as Cenomanian, on about the horizon of the uppermost Horsetown beds, very closely related faunas are widely distributed around the borders of the great Pacific basin. They occur in southern India, Japan, Saghalin, Queen Charlotte Islands, Vancouver, and, according to Steinmann,[4] on the west coast of Chile. While Lower Cretaceous deposits are not so widespread in that region, the character and distribution of their fauna down the west coast of North America seem to indicate that the Pacific was then the home of a uniform fauna, and that it was directly connected with the boreal sea that covered Russia and Siberia, but was not in communication with the Atlantic. This subject can be discussed more satisfactorily after reviewing the Cretaceous of the Texas region.

*The Comanche series.*—In area and in faunas the greatest development of the Lower Cretaceous in the United States is the Comanche series of the Texan region. Its outcrops extend from western Arkansas through southern Indian Territory to Denison and Preston, thence southward through Fort Worth, Austin, and

[1] Sir J. W. Dawson, Trans. Roy. Soc. Canada, Vol. X, 1892, Sec. 4, pp. 81–82.

[2] Jahrb. der k. k. geol. Reichsanstalt, 1894, Bd. 44, p. 476.

[3] Erdgeschichte, Bd. 2, p. 391, 1883.

[4] Neues Jahrb. f. Mineral., Geol. und Paläont., Beilage Bd. 10, 1895, pp. 1–118.

San Antonio to the Rio Grande at Del Rio, covering large areas west of that line. It is known to underlie a large part of Mexico, extending as far west as Arivechi in Sonora. Small outlying areas occur in southern Arizona, at El Paso, Texas, in eastern New Mexico, in Oklahoma, and in southern Kansas. The stratigraphic details have been published mainly by Messrs. R. T. Hill, J. A. Taff, E. T. Dumble, W. F. Cummins, T. W. Vaughan, and C. S. Prosser.

The main features of Mr. Hill's classification of the deposits are as follows :

| | | |
|---|---|---|
| Comanche series | Washita | Shoal Creek limestone,<br>Denison beds,<br>Fort Worth limestone,<br>Preston beds. |
| | Fredericksburg | Caprina (Edwards) limestone,<br>Comanche Peak limestone,<br>Walnut clays. |
| | Trinity | Paluxy sands,<br>Glen Rose limestone and clays,<br>Trinity sands. |

This list gives the principal recognized subdivisions and indicates the lithologic character of the section in central Texas. Calcareous sediments of varying texture and composition largely predominate over all other kinds, thus contrasting strongly with the Shasta deposits. Considerable beds of sand are locally developed in the lower or Trinity division, and in the middle of the Washita clays and sandy layers usually predominate, but as a rule much more than half of the total thickness of the Comanche series consists of calcareous beds. Near the borders of the Comanche sea the limestones decrease in relative thickness or disappear entirely. At El Paso they form but a small proportion of the section, and in the Tucumcari region of New Mexico and in southern Kansas the rocks are all sandstones and clay shales. In the latter region the total thickness is only about 200 feet, and apparently the Washita division is the only one represented. In central Texas the entire series has a thickness of about 1500 feet, which increases southwestward, until

in northern Chihuahua it reaches 4000 feet, as estimated by Dr. C. A. White,[1] and still farther south very much greater thicknesses have been reported. Lithologically the Comanche series as a whole contrasts strongly with the Cretaceous rocks of all other parts of the United States, and indeed of North America, excepting Mexico, which is directly connected with the Texan area. Judging from the descriptions, lithologically similar Cretaceous rocks are developed to some extent in the northern part of South America and in southern Europe. We must go to these regions also, and especially to Portugal and Spain, as Mr. Hill has pointed out, to find closely related faunas.

Fossil plants have been obtained from two horizons, one in the Glen Rose beds of the Trinity division, about 250 feet above the base of the series, and the other in the so-called Cheyenne sandstone, at the base of the Cretaceous section in southern Kansas, but apparently within the Washita division. The plants from the lower horizon, which are directly associated with an abundant marine fauna, have been described by Professor Fontaine.[2] He recognized twenty-three distinct forms, consisting mainly of conifers and cycads, with a fern, an Equisetum, and a few forms of uncertain affinities. Of these seven are represented by identical and six by similar species in the Potomac, four occur in the Wealden of Europe, two in the Urgonian, with an additional one represented by a similar form, and six are peculiar to the Glen Rose. In discussing the age and affinities of these plants Professor Fontaine says: "The plants found at Glen Rose show, so far as can be judged from so imperfect a collection, that the Trinity flora finds its closest resemblance in the older portion of the lower Potomac. There is, however, this important difference: no trace of angiosperms, even the most archaic, has been found in the Texan region. We have only the four elements of the typical Jurassic flora. This, then, makes the Trinity flora somewhat older than that of the oldest Potomac. The absence of angiosperms and the presence of the forms that

[1] Am. Jour. Sci., 3d ser., Vol. XXXVIII, 1889, pp. 440–445.

[2] Proc. U. S. Nat. Museum, Vol. XVI, 1893, pp. 261–282.

are found indicate decidedly that the Trinity flora is not younger than the earliest stage of the Cretaceous. The number of plants found to be identical with certain of those of the oldest Potomac shows that there is little difference in the age of the two formations. The plant-bearing portion of the Trinity is somewhat older than the basal Potomac strata, but the difference in age cannot be great."

In this reasoning it seems to me that too much stress is laid on negative evidence, the absence of angiosperms. The present habits and distribution of plants do not warrant the assumption that a small collection containing only twenty-three species from a very limited area would necessarily include all the important types of plants living at the time they were entombed. The still more striking incompleteness of the Lower Cretaceous faunas will be discussed beyond. It will be remembered that the Kootanie flora and the plants from the Shasta, which were also compared with the Potomac flora, likewise showed the absence of dicotyledons and this was true even in the Horsetown beds which are known from their fauna and stratigraphic position to be far above the base of the Lower Cretaceous.

Among the plants from the Washita horizon in southern Kansas, Dr. Knowlton[1] has recognized seven species of which five are dicotyledons and two are conifers. The species identified had before been found only in the Dakota group in a flora usually assigned to the Cenomanian. It has been shown by Cragin,[2] however, that a part of the beds referred to the Dakota probably belongs to the Comanche series. At all events it is certain that the upper part of the Comanche approaches the Upper Cretaceous in character and it probably is not far from the horizon of the uppermost Potomac beds.

The vertebrates obtained from the Comanche series are few and mostly fragmentary. The descriptions and determinations of Williston,[3] Cragin,[4] and Cope[5] show the presence of fishes,

[1] In a paper by Mr. HILL, Am. Jour. Sci. 3d. ser. Vol. L, 1895, pp. 212–214.
[2] Am. Geologist, Vol. XVI, 1895, pp. 162–165.
[3] Kansas Uni. Quarterly, Vol. III, 1894, pp. 1–4.
[4] Colorado College Studies, Vol. V, 1895, pp. 69–73.
[5] Jour. Acad. Nat. Sci. Phila., Vol. IX, 1895, pp. 443–447.

turtles, crocodiles, and plesiosaurs but they have not furnished any very definite evidence as to the age of the beds. One of the fishes (described by Cope) came from the Glen Rose beds and another from an unknown locality in Texas. All the other vertebrates mentioned are from higher beds near Camp Supply, Oklahoma, and in southern Kansas. Fragmentary bones that are supposed to be dinosaurs but have not been definitely identified have been collected in the Trinity sands by Mr. Hill.

The invertebrate fossils are very numerous throughout almost all of the series above the basal Trinity sands, and constitute several distinct subfaunas though all are connected by species that pass from one zone to another and a few species range through a large part of the series. The species have been mostly described in various books and papers by Roemer, Giebel, Marcou, Shumard, Gabb, White, Hill, and Cragin. The revision of the invertebrate species with the description of new forms contained in recent collections on which I am at present engaged has not progressed far enough to enable me to give complete lists of the fossils of each zone but the general features of the fauna can be profitably discussed and some interesting comparisons can be made.

Mr. Hill's[1] reviews of the subfaunas of the Trinity division and of the Caprina limestone in the Fredericksburg division afford a basis for comparing these horizons with other Cretaceous beds. The list given for the Trinity (Glen Rose) includes about forty invertebrate species and this number will be considerably increased by the study of recent collections. The following characteristic forms, mostly from the same horizon as the Glen Rose plants, are the most important for our present purpose:

Ostrea franklini Coquand
Trigonia stolleyi Hill
Trigonia crenulata (Lam.) Roemer
Trigonia lerchi (Hill)
Trigonia n. sp.
Requienia cf. texana Roemer
Monopleura cf. marcida White
Monopleura cf. pinguiscula White
Cyprina sp.
Natica (Lunatia) pedernalis Roemer

[1] Proc. Biol. Soc. Washington, Vol. VIII, 1893, pp. 9–40, 97–108.

Tylostoma sp.
Glauconia branneri (Hill)
Glauconia cf. helvetica (Pictet and Renevier)
Glauconia cf. picteti Coquand
Nerinea sp.
Neumayria? ? walcotti Hill
Stoliczkaia justinae (Hill)

Excepting the ammonites and the last two species of Trigonia these forms are all very abundant in certain layers and give character to the fauna. The Ostrea is a simple form of little diagnostic value mentioned merely on account of its abundance. The Trigonias represent three groups, two of which, scabræ and quadratæ, are characteristic of the Cretaceous and the other, glabræ, occurs in both Jura and Lower Cretaceous. Requienia and Monopleura are not known outside of the Cretaceous and are found in the Urgonian and higher horizons of Portugal and other southern European countries.[1] *Natica piedernalis* is very like *N. simillinus* Choffat of the Urgonian of Portugal, and Choffat speaks of the great abundance of large Naticas in that horizon, though similar forms also occur in the Valanginian (Lower Neocomian) of the same region. The species of Glauconia are all represented by very similar southern European forms ranging from the Urgonian to the Aptian and perhaps higher. The two species of ammonites are not well enough known to be compared satisfactorily but their nearest relatives apparently are Lower Cretaceous species.

Several other forms have representative species in southern Europe but when the comparisons are all made the final result is not a definite correlation of the lowest fossiliferous beds of the Trinity with any particular horizon of the Lower Cretaceous, though the evidence is clear that it cannot be earlier than the Lower Cretaceous and that it probably is not the base of the Cretaceous.

[1] For stratigraphy and related species mentioned in this discussion see CHOFFAT Recueil de Monog. Stratig. sur le Système Crétacique du Portugal, Lisbonne, 1885 Recueil de Monog. palèont., etc., 1886.

PICTET et RENEVIER. Fossiles du Terrain Aptien de la Perte du Rhone.
PICTET et CAMPICHE. Fossiles du Terrain Crétacé des environs de Sainte Croix
DE LORIOL et DE LORIÈRE. Fossiles du Neocomien superieur de Utrillas.
COQUAND, Monographie paléontologique de l'etage Aptien de l'Espagne.

In the lower part of the Fredericksburg division the Naticas and Tylostomas, in part identical with those of the Trinity continue to play an important part. Here we find the first beds of Gryphaea belonging to the series of species that have often been grouped under the single name *Gryphaea pitcheri* Morton, but which are now separated into several species. These Gryphaeas occur in immense numbers at intervals to the top of the Comanche. Other ostreidae such as Exogyra and Alectryonia have a great development of individuals representing several species. Echinoids, belonging to the genera Enallaster, Hemiaster, Epiaster, Holaster, Holectypus Pseudodiadema, Cidaris, and a few others are also numerous and continue in greater or less abundance in the calcareous beds to top of the series. Among other common forms are Cyprimeria, with difficulty distinguishable from Upper Cretaceous species, several species of Nerinea, Aporrhaidae, etc. Three important species of ammonites, *Engonoceras piedernalis* (von Buch), *Schloenbachia acutocarinata* (Shumard) and *S. trinitensis* (Gabb) also occur.

The Caprina limestone constituting the upper part of the Fredericksburg divison has an interesting and remarkable fauna consisting largely of Requienia, Monopleura, Ichthyosarcolites and other Chamidae, with Radiolites or Sphærulites, Nerinea, many other gastropods, corals, etc. The general assemblage of forms is very much like that in the "Schrattenkalk" or "Caprotina limestone" of the Urgonian and the similarity extends to specific forms in many cases. There is also a more superficial resemblance to the Upper Cretaceous "Hippurite" limestone and it was partly this resemblance that caused Roemer and Heilprin[1] to refer the Comanche series to the Upper Cretaceous. While it would perhaps not be justifiable to call the Caprina limestone Urgonian (as defined by Choffat) or to say that they are exact homotaxial equivalents yet such a statement could not be very far from the truth. The two faunas resemble each other in so many particulars that there must have been free communication between the two areas and the conditions of

[1] Proc. Acad. Nat. Sci. Phila., 1890, pp. 445–469.

marine life must have been very nearly the same in both but as we do not know where the faunas originated nor the direction and rate of migration we can not determine the exact time relations of the deposits.

In the Washita division many of the elements of the Fredericksburg fauna continue either unchanged or but slightly modified. Among identical species that occur in the lower beds of the Washita *Exogyra texana*, *Turritella seriatim-granulata* and *Schloenbachia acuto-carinata* may be mentioned. The *Engonoceras* group[1] of ammonites also reappears in the upper part of the division. Ammonoids are more abundant in the lower Washita (Preston and Forth Worth beds) than in any other part of the Comanche series, though only a few types are represented. Besides those already mentioned, the large *Pachydiscus brazoensis* (Shumard) and *Hamites fremonti* Marcou are abundant, and there is a large development of the genus *Schloenbachia*, mostly of the type *S. inflata* (Sowerby). These forms together with the large *Turrilites brazoensis* Roemer, if occurring in Europe would probably be taken to indicate either uppermost Gault or lowest Cenomanian. A large development of littoral forms in the Denison beds of northern Texas, in the Tucumcari region of New Mexico, and in southern Kansas also gives the fauna a rather modern aspect. But its close relationship with the fauna of the underlying Fredericksburg division and the fact that the next succeeding fauna, that of the Timber Creek beds, contains species of Acanthoceras and other types resembling those that are characteristic of the Cenomanian in Europe tend to place it lower in the Cretaceous system. The uppermost beds of the Washita may possibly be as late as the Cenomanian, but the lower beds in which Schloenbachia is so abundant can hardly be more recent than the Gault. However this point may be decided, the most natural major plane of division in the Texan

[1] This group including *Ammonites piedernalis* van Buch, frequently spoken of as "Cretaceous Ceratites," or as "Buchiceras," in the broad sense in which it was originally defined, is considered characteristic of the southern European or Mediterranean Cretaceous.

Cretaceous is at the top of the Comanche series, and this plane seems to coincide very closely with the top of the Potomac and the top of the Shasta.

It has already been mentioned that the Cretaceous of part of the west coast of South America has some resemblance to the Comanche series, but little is published about the stratigraphy, and in describing the fossils few attempts have been made to indicate the different horizons, so that it is now impossible to make close comparisons. In Peru *Schloenbachia acuto-carinata*, and several large Naticas and Tylostomas, occur with a few other forms related to Comanche species. Similarly in Columbia *Ptychomya buchiana* (Karsten), *Exogyra boussingaulti* d'Orb. and several others have representatives in the Comanche. It has been assumed by some authors that these forms lived in the Pacific basin, and that they prove that the Pacific and Atlantic were connected during Lower Cretaceous time.

By independent comparisons with European Cretaceous faunas—principally northern European in one case and southern or Mediterranean in the other—aided by stratigraphic relation with overlying beds and by the evidence of the fossil plants we have reached the conclusion that the Shasta group and the Comanche series were essentially contemporaneous deposits. And yet their faunas are almost totally distinct. This separateness of the two faunas has frequently been mentioned by Dr. White[1] and the present writer,[2] but the real character of the differences has not been clearly stated. The differences are not dependent on fine discrimination of closely related species. On the contrary, whole genera and in some cases much higher groups that are abundant and characteristic in one area are entirely absent in the other. The following table will exhibit some of the more striking contrasts:

[1] Bull. U. S. Geol. Surv., No. 15, 1885, pp. 30–31; *ibid.*, No. 82, 1891, pp. 180–198.

[2] Bull. Geol. Soc. Am., Vol. IV, 1893, p. 254; JOUR. GEOL, Vol. III, 1895, pp. 858–861; Bull. U. S. Geol. Surv., No. 133, 1896, pp. 27, 31; DILLER and STANTON; Bull. Geo. Soc. Am., Vol. V, 1894, p. 462.

| | Comanche. | Shasta. |
|---|---|---|
| Echinoids | Very abundant in several horizons | Presence barely indicated at one locality in the Knoxville |
| Terebratula | Abundant in two beds | Rarely represented |
| Rhynchonella | Absent | Locally abundant |
| Ostre dæ | Immensely abundant and represented by Ostrea, Gryphaea, Exogyra, and Alectryonia | Very scarce. A small Ostrea in the Knoxville and Exogyra at top of Horsetown |
| Aucella | Absent | Immensely abundant in the Knoxville |
| Trigonia | Common | Common, species not closely related |
| Rudistæ | Abundant in Caprina Limest. | Absent |
| Chamidæ | Abundant in Caprina Limest. | Absent |
| Cyprina | Very abundant | Rare |
| Protocardia | Large species abundant | One very small species of distinct type |
| Cyprimeria | Abundant | Absent |
| Naticidæ | Large species abundant | One or two small forms common |
| Glauconia | Abundant | Absent |
| Turritella | Abundant | Very rare |
| Nerinea | Abundant | Occurrence doubtful |
| Actæonella | Locally abundant | Rare |
| Lytoceras | Absent | Abundant |
| Phylloceras | Absent | Abundant |
| Hoplites | Rare | Common |
| Ancyloceras | Absent | Common |
| Crioceras | Absent | Common |
| Hamites | Abundant in one bed | Absent |
| Pachydiscus | Abundant in one bed | Absent |
| Schloenbachia | Abundant in Fredericksburg and Washita divisions. Several species | One species. Rare at top of Horsetown |
| Engonoceras and related Ammonites | Common | Absent |
| Turrilites | Locally abundant | Absent |
| Belemnites | Absent | Common |

The comparisons could be carried further, showing many other genera that are found in only one of the areas, and that those occurring in both are not represented by closely related species.

The two faunas are complements of each other, and both must be taken together to make up a really representative Lower Cretaceous fauna. Their differences agree in a general way with those that exist between the northern and southern

European Cretaceous, but there are some variations, such as the occurrence of Lytoceras and Phylloceras with boreal forms in the Shasta and their absence from the southern Comanche where they belong.

As to the causes of the sharp contrasts between the Cretaceous faunas of the Texan region and the Pacific Coast, reasons based on the distribution of the fossil plants and on the geographic relations of the deposits have already been given for denying any considerable influence to climate, that is, difference in temperature. Dr. White has argued for the existence of a long, narrow, continental land barrier between the two areas of deposition, and that is doubtless the only single cause that seems at all adequate to explain the facts. But how far south the barrier extended and whether its position was constant we do not know. It is known that the Comanche fauna at one time extended almost to the present Pacific Coast in northern Sonora, and there is evidence that the Pacific fauna may have extended as far east as Catorce in San Luis Potosi, but whether the two seas were really connected or what their exact relations were we can only hope to learn when the details of Mexican geology are fully studied. Besides the existence of a barrier, the depth and clearness of the sea and the character of the bottom also probably had considerable influence. These conditions would at least explain the abundance of echinoids in one case and their absence in the other. The Shasta beds give every evidence of rapid deposition near shore in shallow waters, with usually a muddy bottom, while a large part of the Comanche series was laid down in deeper waters, or at least little influenced by clastic deposits derived directly from the land. One other factor has suggested itself, though it is probably not of much weight, and that is that the gregarious mollusks, like Aucella and the Ostreidæ, actually monopolized the sea bottom where either became well established, so that there was not room for both in the same area.

The study of these two incomplete faunas should emphasize the danger in depending on the statistical method in correlating

formations — the method in which each specific name is treated as a unit and the relative affinities of different deposits or localities are determined automatically by counting the number of common species. Here there are two great series of beds, each with a fairly large fauna, and not very far separated geographically, and yet if directly compared they show no identical and very few related species. Again, these conditions are suggestive when considering a sudden complete change in successive faunas, such as is often seen. If the barrier between the Comanche and Shasta seas had been suddenly removed and the succeeding conditions had been favorable for the continuation of only one of the faunas, we would have had in one of the areas such a complete and sudden change in faunas in two successive beds that a long time interval might have been erroneously invoked to explain it.

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TIMOTHY WILLIAM STANTON.

# CORRELATION OF THE DEVONIAN FAUNAS IN SOUTHERN ILLINOIS.

## INTRODUCTION.

THE Devonian faunas of the interior of America are of two distinct types, and occur in two more or less distinct geological provinces. The eastern interior province is typically represented in New York; it extends westward into Canada and southwestward into the Ohio valley. The western interior province is typically represented in Iowa; it extends to the northwest into British America and is connected with the European region. The southern Illinois Devonian is of much interest because of its geographic position between the New York and the Iowan areas, but in all the study which has hitherto been devoted to the region, it has never been definitely shown with which one of these provinces it is connected. Recent investigation shows the Devonian faunas in southern Illinois to be intimately related to the New York faunas, and that the strata containing them are but a western extension of the formations of the eastern province.

The "Devil's Back Bone" and the "Devil's Bake Oven," near Grand Tower, in Jackson county, Illinois, have long been recognized as localities rich in Devonian fossils. In 1855 Norwood and Pratten[1] described as new several species of *Chonetes* from this locality. In 1867 Hall made frequent mention, in Vol. IV of the Palæontology of New York, of the occurrence of species of brachiopods at the "Bake Oven," Jackson county, Illinois, and a few were described from this locality exclusively. In 1868 the geology of Jackson county was published in Vol. III of the Geological Survey of Illinois, several sketches of the "Bake Oven" and the "Back Bone" being reproduced and mention being made of the fossils collected. In the same volume are

[1] Jour. Acad. Nat. Sci., Phil., ser. 2, Vol. III, pp. 23–32.

descriptions and illustrations of several species of fossils from the locality.

The "Back Bone" is a narrow, rocky ridge, rising about one hundred feet above river level and extending northward from the town of Grand Tower along the east bank of the Mississippi River for a distance of about one-half mile. It consists of strata of Devonian limestone, with beds which are probably of Lower Helderberg age below, dipping to the northeast at an angle of about 25°. The "Bake Oven" is really the northern end of this ridge, but is isolated from the main "Back Bone" by an interval of several hundred feet.

The field work upon which the present paper is based was done in August 1896. As the time which could be devoted to the work was limited, it was concentrated upon the north face of the "Bake Oven." The section here studied is about 167 feet in thickness. An attempt was made to select the fossil-bearing zones in the section, and to make as complete collections from them as the time would allow. Twenty-six zones were recognized, eighteen of them being fossil-bearing to a greater or less extent. Additional time in the field would doubtless materially increase the number of species, and perhaps the number of zones, and a careful examination of the entire "Back Bone" would be exceedingly valuable.

## DESCRIPTION OF THE SECTION, WITH LISTS OF FOSSILS.

The field number given to the section was *5A*. The beds, with their fossil contents, will be described, beginning with the lowest, $5A^1$ and passing upward through the successive zones to $5A^{26}$, which is the highest. The relative abundance of the species is designated as follows: (a) abundant, (c) common, (r) rare.

$5A^1$ About fifteen feet of coarsely crystalline, gray limestone exposed, variable in texture, and often more or less arenaceous, especially near the top. Fossils numerous but not well preserved.

1. *Leptæna rhomboidalis* Wilck. (c).
2. *Chonetes laticosta* Hall? (r).

3. *Orthis* (*Rhipidomella*) *semele* Hall ? (a).
4. *Rhynchonella sp.* (r).
5. *Eatonia sp.* (r).
6. *Cyrtina hamiltonensis* Hall (r).
7. *Spirifer macrothyris* Hall (c).
8. *Spirifer raricostus* Conrad (c).
9. *Nucleospira elegans* Hall ? (r).
10. *Nucleospira ventricosa* Hall (r).
11. *Meristella sp.* (c).
12. *Platyceras sp.* (a).
13. *Orthoceras sp.* (r).
14. *Phacops cristata* Hall ? (r).
15. *Coral*, fragments (r).
16. *Bryozoa*, fragments (c).
17. *Fish teeth*, fragments (r).

*5A*[2] Two and one-half feet of rather coarse, light-colored sandstone. Fossils similar to those in the bed below, but poorly preserved.

1. *Leptæna rhomboidalis* Wilck. (c).
2. *Chonetes laticosta* Hall (r).
3. *Orthis* (*Rhipidomella*) *semele* Hall ? (c).
4. *Eatonia sp.* (r).
5. *Spirifer macrothyris* Hall ? (r).
6. *Spirifer sp.* (r).
7. *Nucleospira elegans* Hall ? ? (r).
8. *Platyceras sp.* (a).
9. *Dalmanites sp.* (r).

*5A*[3] Forty-five feet of impure, thin, irregularly bedded, dark limestone, variable in texture, and affording no fossils. Doubtless a more thorough examination of these beds would disclose a more or less abundant fauna.

*5A*[4] Six inches of impure, shaly limestone, lighter colored than that below and much decomposed upon the surface. Fossils poorly preserved.

1. *Pholidostrophia nacrea* Hall (r).
2. *Chonetes laticosta* Hall (r).
3. *Orthis* (*Rhipidomella*) *sp.* (c).
4. *Rhynchonella sp.* (r).
5. *Centronella glans-fagea* Hall (r).
6. *Spirifer duodenaria* Hall (c).
7. *Spirifer sp.* (r).
8. *Platyceras sp.* (r).
9. *Pleurotomaria ? sp.* (r).
10. *Phacops cristata* Hall ? (r).
11. *Bryozoa*, fragments (a).

*5A*[5]. Ten inches of dark brown, impure, limestone, with chert nodules.

1. *Productella spinulicosta* Hall (r).
2. *Dielasma ? sp.* (r).
3. *Spirifer grieri* Hall (r).
4. *Platyceras*, cf. young of *P. bucculentum* Hall (r).
5. *Phacops cristata* Hall ? (r).
6. *Bryozoa*, fragments (a).

*5A*[6]. Four and one-half feet of unevenly bedded, partially crystalline, impure brown limestone.

1. *Strophodonta patersoni* Hall (c).
2. *Strophonella ampla* Hall (r).
3. *Chonetes mucronata* Hall (a).
4. *Orthis* (*Rhipidomella*) *vanuxemi* Hall *var?* (r).
5. *Orthis* (*Schizophoria*) *propinqua* Hall (a).
6. *Atrypa reticularis* Linn. (c).
7. *Cyrtina hamiltonensis* Hall (r).
8. *Spirifer grieri* Hall (r).
9. *Paracyclas elliptica* Hall (r).
10. *Platyceras sp.* (c).
11. *Lichas* (*chonolichas*) *eriopsis* Hall ? (r).
12. *Phacops cristata* Hall ? (r).
13. *Cystodictya sp.* (a).

*5A*[7]. Six feet four inches of thin, unevenly bedded gray-brown limestone nearly identical in lithological characters with the last.

1. *Strophodonta patersoni* Hall (c).
2. *Chonetes mucronata* Hall (a).
3. *Orthis* (*Rhipidomella*) *vanuxemi* Hall *var?* (c).
4. *Atrypa reticularis* Linn. (c).
5. *Spirifer varicosus* Hall (r).
6. *Nucleospira concinna* Hall ? (r).

*5A*[8]. One foot four inches of impure, semicrystalline, brown limestone with numerous fragments of corals too imperfectly preserved for identification.

*5A*[9]. Three feet of limestone similar to the last but without fossils.

*5A*[10]. One foot of limestone similar to the last.

1. *Strophodonta concava* Hall (r).
2. *Corals*, imperfect fragments (a).

*5A*[11]. Three feet ten inches of hard, brittle, semicrystalline, much fractured limestone, with an abundant fauna.

1. *Strophodonta patersoni* Hall (a).
2. *Strophodonta concava* Hall (a).
3. *Strophodonta perplana* Conrad (c).
4. *Strophodonta inequistriata* Conrad (c).

5. *Strophodonta demissa* Conrad (r).
6. *Pholidostrophia nacrea* Hall (r).
7. *Leptæna rhomboidalis* Wilck. (r).
8. *Orthothetes chemungensis* Conrad var. *arctostriata* Hall (r).
9. *Orthothetes chemungensis* Conrad var. *pandora* Billings (c).
10. *Chonetes mucronata* Hall (a).
11. *Productella spinulicosta* Hall (r).
12. *Orthis* (*Rhipidomella*) *vanuxemi* Hall *var.?* (a).
13. *Orthis* (*Schizophoria*) *propinqua* Hall (r).
14. *Rhynchonella louisvillensis* Nettelroth ? (r).
15. *Rhynchonella cf. horsfordi* Hall (r).
16. *Rhynchonella* (*Pugnax*) *sp.* (r).
17. *Atrypa reticularis* Linn. (a).
18. *Cyrtina hamiltonensis* Hall (a).
19. *Spirifer varicosus* Hall (a).
20. *Spirifer duodenaria* Hall (c).
21. *Nucleospira concinna* Hall (r).
22 *Paracyclas elliptica* Hall (r).
23. *Modiomorpha ? cf. M. recta* Hall (r).
24. *Grammysia cf. rhomboidalis* M. & W. (r).
25. *Conocardium cuneus* Conrad (c).
26. *Aviculopecten sp.* (a).
27. *Pterinea sp.* (r).
28. *Pterinea flabellum* Conrad ? (r).
29. *Platyceras bucculentum* Hall ? (c).
30. *Callonema lichas* Hall ? (c).
31. *Loxonema ? cf. L. pexatum* Hall ? (c).
32. *Bellerophon 2 sp.* (r).
33. *Lichas* (*Ceratolichas*) *cf. grypes* Hall (r).
34. *Dalmanites cf. calypso* Hall *cf. erina* Hall (c).
35. *Phacops cristata* Hall ? var. (r).
36. *Zaphrentis ?* imperfect fragments (c).
37. *Bryozoa* fragments (c).
38. *Fish Teeth* fragments (r).

*5A*[12]. Nine feet of impure, brown limestone with thin bands of chert. No fossils collected.

*5A*[13]. Five feet of limestone similar to the last.

1. *Strophodonta perplana* Conrad (c).
2. *Strophodonta demissa* Conrad (r).
3. *Strophodonta inequiradiata* Hall (c).
4. *Orthothetes chemungensis* Conrad *var. pandora* Billings (c).
5. *Chonetes mucronata* Hall (a).

6. *Productella Spinulicosta* Hall (r).
7. *Pentamerella cf. arata* Conrad (r).
8. *Rhynchonella sappho* Hall (r).
9. *Rhynchonella cf. horsfordi* Hall (r).
10. *Dielasma ? sp.* (r).
11. *Atrypa reticularis* Linn. (a).
12. *Spirifer sp.* (r).
13. *Paracyclas elliptica* Hall (r).
14. *Phacops cristata* Hall ? *var.* (r).
15. *Bryozoa*, fragments (a).

*5A* [14]. Twenty feet of impure brown limestone, variable in character and texture, thin bedded and shaly in part.

*5A* [15]. Five feet of impure reddish brown limestone.

1. *Strophodonta concava* Hall (a).
2. *Strophodonta demissa* Conrad (c).
3. *Leptæna rhomboidalis* Wilck. (a).
4. *Chonetes cf. deflecta* Hall (a).
5. *Orthis* (*Rhipidomella*) *vanuxemi* Hall (c).
6. *Paracyclas elliptica* Hall (r).
7. *Bellerophon sp.* (r).
8. *Gomphoceras lunatum* Hall ? (c).
9. *Gomphoceras impar* Hall ? (c).

*5A* [16]. Three feet ten inches of brown limestone.

1. *Strophodonta inequiradiata* Hall (r).
2. *Chonetes cf. deflecta* Hall (r).
3. *Orthis* (*Rhipidomella*) *vanuxemi* Hall ? var. (a).
4. *Orthis* (*Schizophoria*) *? sp.* (a).
5. *Spirifer sp.* (r).
6. *Paracyclas elliptica* Hall (r).

*5A* [17]. Five feet five inches of impure brown limestone. No fossils collected.

*5A* [18]. Three feet six inches of impure, reddish-brown limestone, composed almost wholly of a single species of *Chonetes*.

1. *Chonetes yandellana* Hall (a).
2. *Productella spinulicosta* Hall ? (r).
3. *Productella sp.* (r).
4. *Camarophoria sp.* (r).
5. *Dielasma cf. D ? navicella* Hall (r).
6. *Paracyclas elliptica* Hall (r).
7. *Platyceras sp.* (r).

*5A* [19]. Nine feet of impure brown limestone with few fossils.

*5A*[20]. Two feet impure shaly brown limestone with multitudes of a single species of *Chonetes*.

1. *Chonetes littoni* N. & P.? (a).
2. *Spirifer fornaculus* M. & W. (r).

*5A*[21]. Six feet of impure, thin bedded, brown limestone with few fossils.

*5A*[22]. Six inches impure brown limestone.

1. *Pholidostrophia nacrea* Hall (a).
2. *Productella spinulicosta* Hall (r).
3. *Dielasma sp.* (r).
4. *Atrypa reticularis* Linn. (r).
5. *Spirifer ziczac* Hall ? (a).
6. *Spirifer fornaculus* M. & W. (r).
7. *Favosites ? sp.* (r).

*5A*[23]. Three feet of dark, often nearly black, somewhat siliceous limestone with many fossils.

1. *Strophodonta inequiradiata* Hall (a).
2. *Strophodonta demissa* Conrad (c).
3. *Pholidostrophia nacrea* Hall (a).
4. *Leptæna rhomboidalis* Wilck. (a).
5. *Chonetes deflecta* Hall (a).
6. *Chonetes pusilla* Hall (a).
7. *Orthis* (*Schizophoria*) *iowensis* Hall (c).
8. *Spirifer fornaculus* M. & W. (c).
9. *Athyris vittata* Hall (c).
10. *Paracyclas elliptica* Hall (c).
11. *Paracyclas lirata* Conrad (r).
12. *Pleurotomaria sp.* (c).
13. *Bellerophon sp.* (r).
14. *Orthoceras sp.* (r).
15. *Phacops rana* Green (a).
16. *Proetus rowii* Green (r).
17. *Zaphrentis? sp.* (r).
18. *Cystodictya sp.* (a).

*5A*[24]. Nine feet of unexposed, covered at the time of examination with mud and water.

*5A*[25]. Three feet of dark brown impure limestone made up almost exclusively of specimens of *Chonetes coronata*.

1. *Chonetes coronata* Hall (a).
2. *Tropidoleptus carinatus* Conrad (a).
3. *Spirifer fornaculus* M. & W. (a).

4. *Bellerophon sp.* (r).
5. *Gyroceras cf. trivolve* Conrad (r).
6. *Tentaculites bellulus* Hall ? (c).
7. *Phacops rana* Green (c).
8. *Proetus canaliculatus* Hall (r).
9. *Zaphrentis sp.* (r).
10. *Cystodictya sp.* (c).

*5A*[14]. Four inches of impure brown limestone like the last, but with few specimens of *Chonetes coronata.*

1. *Orthothetes chemungensis* Conrad *var pandora* Billings (r) .
2. *Chonetes coronata* Hall (c).
3. *Spirifer fornaculus* M. & W. (a).
4. *Gomphoceras sp.* (r).

## DISCUSSION OF THE FAUNAS.

From a general survey of the entire fauna of the section, seven conspicuous divisions may be recognized. The first of these include zones *5A*[1] and *5A*[2]. The conspicuous species are *Orthis* (*Rhiphidomella*) *semele?* and *Platyceras sp. Orthis* (*Rhipid.*) *semele* was originally described by Hall from very imperfect material found in the Onondaga limestone in Erie county, N. Y. The Illinois specimens are not perfectly preserved, but seem to agree more nearly with this species than with any other. The *Platyceras* is of a type which might be present in any fauna from the Lower Helderberg to the Hamilton inclusive. Well preserved specimens of *spirifer macrothyris* and *spirifer raricostus* are present, which are good Upper Helderberg species. Associated with these are *Nucleospira ventricosa* and *Nucleospira elegans?* which were described from the Lower Helderberg, and an undescribed species of *Eatonia*, which genus has not hitherto been recognized above the Oriskany. There is no fauna comparable to this one in the western interior Devonian province, but in the eastern province this association of species is about equivalent to the lower half of the Upper Helderberg group in the New York series.

The second division of the general fauna includes zones *5A*[4] to *5A*[13]. The association of species in these zones is a typical

Corniferous limestone fauna, as seen in Indiana, Ohio, and New York. The conspicuous species in the fauna are the large and robust *Strophodontas*, the *Atrypa reticularis* of the large, robust form so common at the falls of the Ohio, *Spirifer varicosus*, *Spirifer duodenaria*, *Orthis* (*Schizophoria*) *propinqua*, *Paracyclas elliptica*, *Conocardium cuneus*, *Lichas* (*Ceratolichas*) *cf. grypes*, *Dalmanites cf. calypso cf. erina*, etc. Nowhere in the western interior province does a fauna at all allied to this one occur, but it is identical with the Corniferous fauna of the eastern province.

The third division may be called the *Gomphoceras* zone, and includes only the bed numbered *5A*[15]. It is characterized by numerous specimens of several large, robust species of *Gomphoceras*. The specimens as they occur on the surface of the outcrop are generally too imperfect for certain identification, but are of a general type of the genus which is common in both the Corniferous and the Hamilton faunas. The associated species are nearly all identical with those in the Corniferous fauna below.

The fourth division is the *Chonetes yandellana* zone, *5A*[18]. The bed is made up almost exclusively of multitudes of specimens of this one species, all the others recorded being rare or uncommon.

The fifth division is the *Chonetes littoni?* zone, *5A*[20]. It is similar to the *Chonetes yandellana* zone in being made up almost entirely of great numbers of individuals of a single species of *Chonetes*. *C. littoni*, with three other species of the same genus, was originally described from this locality by Norwood and Pratten, but their descriptions and figures are so imperfect that it is difficult to recognize their species. In the faunas of the section there are three conspicuous *Chonetes* zones, each containing exclusively a single species of the genus. Three of Norwood and Pratten's species, *C. maclurei*, *C. martini*, and *C. tuomyi*, may be certainly identified as different stages of a single species, *C. coronatus*, which characterizes the uppermost *Chonetes* zone. The chances are, therefore, that their fourth species, *C. littoni*, is

either one or the other of the two additional conspicuous species at the locality, and from careful examination and comparison of the specimens, descriptions and figures, it seems most probable that the species occurring in such numbers in zone *5A* [19] is the *C. littoni* of these authors.

The sixth division is zone *5A* [23], and has a fauna quite different from any of those below. *Leptæna rhomboidalis* is the most abundant species. Some of the additional conspicuous species are *Chonetes deflecta* and *Chonetes pusilla*, which are apparently variations of a single species, *Pholidastrophia nacrea*, *Athyris vittata* of the type common at the falls of the Ohio, *Phacops rana*, *Paracyclas elliptica* and *Paracyclas lirata*. As a whole the fauna is of a Hamilton facies, but is more like the Hamilton fauna at the falls of the Ohio than the typical New York fauna. *Orthis* (*Schizophoria*) *iowensis* is an uncommon species which is conspicuous in the Devonian faunas of Iowa, but is absent from the New York faunas until after the incursion of the Chemung faunas from the west.

The seventh and last division is zone *5A* [25], and may be termed the *Chonetes coronata* zone. The bed is made up of multitudes of individuals of *Chonetes coronata*, with perhaps one-tenth as many individuals of *Tropidoleptus carinatus*. Both of these species are peculiar forms and are characteristic of the New York Hamilton. They appear suddenly both in the New York and the Illinois localities without any known forerunners. *Tropidoleptus carinatus* is an abundant species in the South American Devonian faunas, and *Chonetes coronata* is of a type otherwise unknown in North America, but common in South America, where it is represented by *C. arcei Ulr.*, *C. rücki Ulr.*, and other species. There is evidence in the Hamilton fauna of the east-American province of an immigration from the southern hemisphere which did not affect the western Devonian faunas. The details of this epoch in Devonian history are not yet fully understood, but the presence of this *Chonetes coronata* and *Tropidoleptus* fauna marks the point where this immigration first made itself felt in the southern Illinois region.

## CONCLUSION.

It is believed that the facts here set forth satisfactorily demonstrate that the Devonian faunas in southern Illinois are not related to the Iowan Devonian faunas as has sometimes been suggested, but are a western extension of the faunas of the New York province. At the "Bake Oven" section the fauna of the lowest beds is of an age corresponding to the lower portion of the Upper Helderberg period, while the uppermost faunas are of Hamilton age. The line of demarkation between the Upper Helderberg and Hamilton faunas cannot be exactly drawn, but it comes somewhere between zones $5A^{15}$ and $5A^{23}$.

In conclusion I wish to acknowledge the assistance given by Mr. A. W. Slocom, who has skillfully prepared the material for study.

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# *EDITORIAL.*

THE attendance at the Detroit meeting of the American Association for the Advancement of Science was notably smaller than usual, a result doubtless due in part to the meeting of the British Association at Toronto which followed at such an interval as to invite busy men to select the one at the expense of the other. The attendance upon the geological section was also adversely affected by the International Congress at St. Petersburg. The papers presented, however, were perhaps even more than usually important and interesting. The location of the meeting naturally invited an unusual number of papers relative to the problems of the Great Lake Basins and these easily took precedence. The widest popular interest was undoubtedly called forth by Mr. Gilbert's announcement of a definite tilting of the area of the lake basins towards the southwest. His deduction that the rate of change amounted to five inches per hundred miles per century, and his prophecy that at a specified date the drainage would be reversed, Niagara abandoned, and Detroit and Chicago flooded, naturally created something akin to a sensation in the great cities of the lakes. Incidentally this contribution to prophetic geology is having a good effect in removing the too wide impression that geology is a science of the ancient earth. The present and future belong to it as much as the past. The activity of recent years in current geomorphy is helping to awaken an appreciation of contemporaneous geology. A few decisive predictions will doubtless establish the value of prognostic geology.

This is not the first time that Mr. Gilbert has essayed the rôle of geological prophet, but it is, we believe, the first instance in which he has given us a definite time factor which holds out

the prospect that we may be able to bring him face to face with his responsibilities at a fixed day of fulfillment, though his dates are inconveniently distant. A prophecy which definitely courts a test of its accuracy by giving dates and amounts has a grateful moral flavor. The prospect of honor for fulfillment and punishment for failure is equitably distributed. Writing from this doomed locality we cannot lay claim to that indifference to results which is the prerequisite of complete impartiality in weighing the merits of the prophecy, but we have this comforting alternative that whatever the outcome we shall be able either to rejoice in the triumph of a friend or else join in the laugh of our neighbors at his failure.

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One of the features of especial interest at the Detroit meeting was the joint session of the anthropological and geological sections for the discussion of the relics of man found on the Delaware at Trenton, N. J., participated in by Putnam, Knapp, Kümmel, Wright, Holmes, Mercer, Wilson and Salisbury. Previous to the meeting all of these participants had visited the ground where excavation under the direction of Professor Putnam has been for some time in progress, and were thus armed with fresh facts from personal observation. The good influence of the "higher criticism" was manifest in the great care obviously taken in making and presenting the observations and in the critical and cautious attitudes assumed in their interpretation. The discussion was an altogether admirable one and formed an important episode in the progress of anthropic geology in this country. The discussion was essentially confined to the interpretation of a surface bed of sand three or four feet thick embracing scattered pebbles and irregular seams of ferruginous and silty materials, and of the artifacts found in it. This superficial bed rests upon the glacial gravels and lies on the brink of the terrace which overlooks the Delaware bottoms. The geological discussion centered upon the origin of this sandy deposit. The majority opinion and the weight of evidence seemed on the whole to favor a wind origin. No substantial evidence that it was of glacial or glacio-fluvial

origin, or that it was contemporaneous with any part of the ice age was presented. The anthropological discussion centered upon the question whether any civilization different from that of the early Algonkian Indians was shown by the relics. The former contention that the base of the deposit only carries argillite artifacts, while the upper carries quartz and jasper flakes also, was weakened by the reporting of a few jasper and quartz chips from the lower part. The hypothesis that the artifacts are palæolithic was weakened by the discovery of a small arrowhead in the heart of the deposit. On the whole the discussion seemed to leave the general impression that the evidence of any very ancient or very primitive form of civilization at this locality is of a quite slender and doubtful nature. The hypothesis of a glacial man was scarcely in serious discussion although incidentally alluded to, there being no proof that the beds are of glacial age. No new evidence of relics in the undoubted glacio-fluvial beds below was presented.

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At the Toronto meeting a similar joint session was held at which the broader subject of ancient man in America was discussed. The added point of interest there was the attitude of the British geologists and archæologists who are familiar with the character of the evidence in Europe where the antiquity of man is not seriously questioned. Their general disposition toward the evidence presented was that of marked conservatism. The foreign anthropologists and geologists seemed keenly alive to the inherent incongruities and self-destructive aspects of much of the supposed evidence for the great antiquity of man in America.

The influence of the two discussions will be very wholesome both within and without scientific circles.

The geological papers presented at the meeting of the British Association at Toronto were notable for the wide range of their themes and their high order of excellence. T. C. C.

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Papers offered at the Detroit meeting of the Geological Society of America, August 10, 1897:

"The Granite Mountain Area of Burnet County, Texas." By FREDERIC W. SIMONDS, Austin, Texas.

"Exposures near Detroit of Helderberg Limestone and Associated Gypsum, Salt and Sandstones." By W. H. SHERZER, Ypsilanti, Mich.

"Notes on the Geology of the Lower Peninsula of Michigan." By ALFRED C. LANE, Houghton, Mich.

"The Nomenclature of the Carboniferous Formations of Texas." By ROBERT T. HILL, Washington, D. C.

"Stratigraphy and Structure of the Puget Group, Washington." By BAILEY WILLIS, Washington, D. C.

"The Loess as a Land Deposit." By J. A. UDDEN, Rock Island, Ill.

"Ice-transported Bowlders in Coal Seams." By EDWARD ORTON, Columbus, O.

"Clay veins Vertically Intersecting Coal Measures." By W. S. GRESLEY, Erie, Pa.

"Analogy Between Declivities of Land and Submarine Valleys." By J. W. SPENCER, Washington, D. C.

"Great Changes of Level in Mexico and the Interoceanic Connections." By J. W. SPENCER, Washington, D. C.

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Papers offered at the Session of the Geological Section of the American Association for the Advancement of Science, Detroit, August 11-13, 1897:

Address of VICE-PRESIDENT WHITE. Subject: "The Pittsburg Coal Bed."

"The Geological Age and Fauna of the Huerfano Basin in Southern Colorado." By PROFESSOR HENRY F. OSBORN, Columbia University, New York, N. Y.

"An Account of the Researches relating to the Great Lakes." By DR. J. W. SPENCER, Washington, D. C.

"Lake Chicago and the Chicago Outlet." By FRANK LEVERETT, U. S. Geological Survey, Denmark, Ia.

"The Lower Abandoned Beaches of Southeastern Michigan." By FRANK B. TAYLOR, Fort Wayne, Ind.

"Some Features of the Recent Geology around Detroit." By FRANK B. TAYLOR, Fort Wayne, Ind.

"Recent Earth Movement in the Great Lake Region." By G. K. GILBERT, U. S. Geological Survey, Washington, D. C.

"Preglacial Topography and Drainage of Central-Western, New York." By PROFESSOR H. L. FAIRCHILD, University of Rochester, Rochester, N. Y.

"A Supplementary Hypothesis respecting the Origin of the American Loess." By PROFESSOR T. C. CHAMBERLIN, University of Chicago, Chicago, Ill.

"Progress of Hydrographic Investigations of the U. S. Geological Survey." By F. H. NEWELL, U. S. Geological Survey, Washington, D. C.

"Stylolites." By PROFESSOR T. C. HOPKINS, State College, Centre Co. Pa.

"A suggestion in regard to the Theory of Volcanoes." By PROFESSOR WILLIAM NORTH RICE, Wesleyan University, Middletown, Conn.

"The Ores and Minerals of Cripple Creek, Colorado." By H. P. PARMALEE, Charlevoix, Mich.

"Observations on the Genus Barrattia." By PROFESSOR R. P. WHITFIELD, American Museum Natural History, New York, N. Y.

"Ice Jams and what they Accomplish in Geology." By DR. M. A. VEEDER, Lyons, N. Y.

# *Reviews.*

*Geological Survey of Canada, Annual Report, Vol. VIII, 1895.* By G. M. Dawson, Director, Ottawa, 1897.

This large volume embracing over a thousand pages contains a summary report of the work of the geological survey for the year 1896 by Director Dawson; "A report on the Country between Athabasca Lake and Churchill River" by J. Burr Tyrrell and D. B. Dowling; "A Report on the Geology of a Portion of the Laurentian Area lying to the North of the Island of Montreal," by Frank D. Adams, with appendices; "A Report on Explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Manicuagan and Portions of other Rivers in 1892–5," by A. P. Low, with biological, petrological and mineralogical appendices; "A Report of the Section of Chemistry and Mineralogy," by G. C. Hoffman; and of the "Section of Mineral Statistics and Mines," by E. D. Ingall. The report is accompanied by numerous maps and by photographic and other illustrations.

The summary by the director possesses the clearness and comprehensiveness which characterize all of Dr. Dawson's general papers. It gives an admirable synoptical review of the widely extended and varied enterprises of this great survey. The report of Mr. Tyrrell, and his assistant, Mr. Dowling, embraces observations made chiefly in the summer of 1892. They cover Recent, Pleistocene, Cretaceous, Keeweenawan, Huronian and Laurentian formations, besides topographic, biologic and other matters. The most important contributions are those which relate to the Athabasca sandstone, which appears to be the equivalent of the Keeweenawan of Lake Superior, to the Laurentian gneisses and associated formations, and to the Pleistocene deposits. These confirm and extend the previous well-known determinations of Mr. Tyrrell in the region west of Hudson Bay.

Dr. Adams' discussion of the crystalline rocks north of Montreal shows notable progress in the elucidation of the difficult problems of that region. Among the most important features are the advances made in the discrimination of original igneous gneisses from those of

metamorphic origin and the additional evidence of the degenerative granulation of the crystalline rocks as a result of great pressure.

The report of Mr. Low on his remarkable explorations in the Labrador peninsula contain a vast amount of new and important information respecting this heretofore *terra incognita*. It is impossible to satisfactorily summarize this. It shows that besides vast areas of gneisses and granitoid rocks presumably referable to the Laurentian series, there are extensive belts of later rocks of clastic origin referable to the Huronian and Cambrian series as interpreted by the Canadian survey. The rocks classified as Cambrian comprise beds of arkose rock, sandstone, chert, dolomite, felsitic shale, argillite and argillaceous shale, together with gabbro, diabase and fine-grained decomposed traps and volcanic conglomerates. They appear to embrace those debatable beds which are referred by some of the United States geologists to pre-Cambrian horizons. There is ground to hope that this extended area of these formations will afford the means for their complete elucidation. The observations of Mr. Low have made it clear that this great Labradorean area has a complex geological structure and is far from being properly characterized as simply Laurentian or even Archæan.

Mr. Low's contributions to glacial geology are very important. They show an outward movement in all directions from the center of the peninsula. He locates the central névé ground (which is characterized by only slight traces of glacial motion) midway between the east and west coasts of the peninsula, and between 53° and 55° latitude. Its southern boundary is in places from 150 to 200 miles north of the southern water-shed. The report is accompanied by "Notes on the Microscopical Structure of some of the Rocks of the Labrador Peninsula," by Mr. W. F. Ferrier.

The chemical, mineralogical and statistical reports embrace a large mass of valuable data. Altogether the report is one of the most important issued by the survey. T. C. C.

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*Iowa Geological Survey, Vol. VI. Report on Lead, Zinc, Artesian Wells, etc.* SAMUEL CALVIN, State Geologist, A. G. LEONARD and H. F. BAIN, Assistant State Geologists. Des Moines, 1897.

This volume of 487 pages embraces reports on the "Lead and Zinc Deposits of Iowa," by A. G. Leonard; "The Sioux Quartzites and Cer-

tain Associated Rocks," by S. W. Beyer; "The Artesian Wells of Iowa," by W. H. Norton, and the "Relations of the Wisconsin and Kansan Drift Sheets in Central Iowa, and Related Phenomena," by H. Foster Bain.

Mr. Leonard describes the formations which embrace or are contiguous to the lead and zinc deposits, the mode of occurrence of these deposits, the association of the minerals and the particular forms of the ores. To these he adds special descriptions of the mines and a discussion of the origin of the deposits and the general methods of working them. He makes an important contribution to the general relationship of the ores in showing that in the Dubuque district zinc occurs in the higher horizons of the Galena limestone associated with the lead. This appears to require a modification of the generalization previously reached in Wisconsin and northwestern Illinois to the effect that the zinc usually occurs in lower horizons than the lead. The additional data appear to indicate that in their original deposition in the strata the zinc and lead were immediately associated with each other, and that their distribution in the crevices as the result of secondary action has been dependent upon the conditions of precipitation which were not uniform in all districts. Mr. Leonard regards the Archæan rocks as the original source of the lead and zinc, having been derived thence by surface decomposition and carried into the Silurian sea, from which in turn they were precipitated along with the gathering limestone. The precipitating agency he thinks was chiefly organic. He discusses the different theories of the localization of the metallic deposits, and concludes that on the whole Chamberlin's theory of oceanic currents offers the most plausible explanation. He regards the crevices as chiefly due to flexures of the strata aided by solution. He holds to the view that the minerals were carried into the crevices by lateral secretion from the surrounding limestones.

The rocks which Mr. Beyer finds associated with the Sioux quartzites embrace a series of slates and some olivine diabases. The slates he finds to conformably overlie the quartzite and to be somewhat interbedded with or graduated into the upper quartzitic layers. He regards the slates as an upward extension of the quartzite formation. In respect to the thickness of the quartzite formation he favors the lower estimate of Todd (1500 feet) rather than the higher estimate of Irving (3000 to 4000 feet), but regards both estimates as doubtful. He confirms the view of Irving that the quartzites were formed from siliceous

sandstones by interstitial growth. He favors the view that the quartzites are of early age, the probable equivalents of the Mankato and Baraboo quartzites.

Professor Norton introduces his discussion by a statement of the theory of artesian wells and their requisite conditions. He then describes the conditions of the Iowa field, discussing the geological structure, the area of supply, the reservoir and the conditions of transmission. This is followed by a description of the wells classified by sections. Under the head of chemistry of the waters he treats of the mineral ingredients, of the interpretation of analyses, and of the classification based on these; and also of the therapeutic, sanitary, and industrial qualities of the waters. He also touches upon the questions of public supply, of cost, of purity and of practical matters relative to drilling, thus giving to the report much popular as well as scientific interest.

The paper of Mr. Bain embraces a special study of the relations of the two drift sheets found in the vicinity of the capital. After a careful statement of the history of investigations, he describes, critically, the Des Moines lobe of the Wisconsin drift as it appears in Pope, Dallas, and Guthrie counties, and follows this by a similar critical discussion of the characteristics of the older drift which underlies it, and occupies the region lying to the south. An important feature of the paper is the discussion of time ratios as indicated by erosive and other phenomena. From the computation of special cases selected as being best suited to the purpose, he reaches the conclusion that the time ratio between the Wisconsin and the Kansan ranges from 1:10 to 1:15, being probably nearer the latter than the former.

The Iowa survey is to be congratulated upon the excellence of this report. T. C. C.

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*Geology and Natural Resources of Indiana; Twenty-first Annual Report.* By W. S. BLATCHLEY, State Geologist. Indianapolis, 1897.

This report of 718 pages embraces "An Introduction" and "The Natural Resources of Indiana," by W. S. Blatchley; "The Petroleum Industry in Indiana," by the same; "The Composition of Indiana Coals," by W. A. Noyes; "Some Notes on the Black Slate or Genessee Shale of New Albany," by Hans Duden; "The Indiana Caves and their Fauna," by W. S. Blatchley; "A Report on the Geology of the Middle

and Upper Silurian Rocks of Clark, Jefferson, Ripley, Jennings and Southern Decatur Counties," by August F. Foerste; "The Bedford Oölitic Limestone of Indiana," by T. C. Hopkins and C. E. Siebenthal; "The Report of the State Natural Gas Supervisor," by J. C. Leach; "The Report of the State Inspector of Mines," by Robert Fisher; "The Report of the State Supervisor of Oils," by C. F. Hall; "The Geology of Vigo County," by J. T. Scoville; and "A Catalogue of the Ferns and Flowering Plants of Vigo County," by W. S. Blatchley.

The paper of the state geologist on the petroleum industry of Indiana treats of the geographical and geological distribution of petroleum, of its origin, and the physical and chemical properties of the Indiana petroleum. He describes the oil fields by counties, introducing local details. The report closes with a chapter of a practical and economical character relating to the choosing of a locality for operating, the locating, drilling, and shooting of the wells, and their cost, accompanied by statistics with regard to the Indiana oil production.

Mr. Noyes gives the results of the twenty-seven analyses of coals, with an interpretation of results and a comparison of the coals.

The Notes on the Genessee Shale of New Albany, embrace chemical analyses, a statement of the previous experiments in utilizing the shale, and of new methods proposed by Mr. Duden, together with a discussion of the source of the bitumen embraced in the shales. The paper is accompanied by a description of some of the fossil plants discovered.

The discussion of the Indiana caves by the state geologist embraces descriptions of eighteen caves located in Owen, Monroe, Lawrence, Washington, and Crawford counties, accompanied by maps and photographic illustrations. This is supplemented by a description of the fauna of the caves, embracing mammals, batrachians, fishes, insects, and crustaceans, the descriptions being by W. S. Blatchley, J. M. Aldrich, Mary Murtfeldt, H. F. Wickham, and W. P. Hay.

In his discussion of the geology of the Middle and Upper Silurian rocks of the southeastern counties of Indiana, Dr. Foerste subdivides the formations for the purpose of more exact and refined study, as follows in descending order: The Niagara, into (1) the Louisville limestone or Utica lime rock, (2) the Waldron shale, (3) the Laurel limestone or Cliff rock, (4) the Osgood or cystidian beds, divided in places into (*a*) the Upper Osgood clay, (*b*) the Osgood limestone, (*c*) the Lower Osgood Clay. The Clinton group he does not subdivide.

The Cincinnati group he divides into (1) the Madison beds and their northern equivalents, (2) the richly fossiliferous shales and limestones below the Madison beds, (3) the Gastropod or Marvel Hill beds, and (4) a great section below not studied. The author enters into detail in the discussion of these formations and their special features in the more important localities, in the course of which the fossil contents receive special attention.

The discussion of the Bedford Oölitic limestone by Hopkins and Siebenthal is introduced by a discussion of the general geographical and stratigraphical features of the formation and associated strata. The body of the report embraces a discussion of the structural and economic features of the Bedford limestone, a discussion fully warranted by the very extensive use of the limestone as a building material. The treatment covers the results of both physical and chemical tests, and embraces the determination of the strength of the rock in various attitudes, its elasticity, absorption, resistance to fire and to water, its workability and accessibility. A chapter is devoted to the commercial features of the formation embracing the quarrying, handling of the stone, methods of work, machinery used, uses and adaptabilities of the stone, its transportation facilities, statistics of production, etc., which is followed by local descriptions. The discussion is closed by a classification of oölitic limestones.

The reports of the supervisors of gas, of mines, and of oil, embrace statistical and economic matter of value to those interested in these industries.

Dr. Scoville's "Geology of Vigo County" embraces the general topography and stratigraphy of the region, the ancient channels which cross the territory, but are now buried by the glacial deposits, the Pleistocene glacier of Vigo county, and the recent geology, embracing the soils and archæology.

The report has the same general form as preceding annual reports, but is more fully and better illustrated. T. C. C.

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*Geological Survey of Alabama, Eugene Allen Smith, State Geologist. Report on the Valley Regions. Part II, On the Coosa Valley.* By HENRY MCCALLEY, Assistant State Geologist.

In this report the physical features of the Coosa Valley Region are classified into natural divisions, consisting of (1) broad, flat-topped

synclinal mountains bounded by bluffs; (2) uniform anticlinal valleys with sharp, well defined limits; (3) monoclinal mountains with steep northwest sides and gentle southeast slopes; (4) monoclinal valleys with ill-defined and irregular northwest limits; (5) flatwoods; (6) irregular valleys with jagged edges; and (7) chert hills and ridges. Each of these subdivisions is described and illustrated by local examples. The geology is introduced by brief reference to the changes due to denudation, after which the faults of the region, to the number of sixteen, are named and described. A general description of the geological formations of the region, ranging from the crystalline Talladega slates to the Lafayette, follows. The minerals, rocks, and other substances of special use and interest, are next discussed, and this is followed in turn by a chapter devoted to the soils, agricultural features, timber, water power, climate, health, and drainage of the region. The remainder of the report is occupied with county details, embracing Etowah, St. Clair, Jefferson, Tuscaloosa, Bibb, Shelby, Talladega, Calhoun, Cherokee, Clayborn, Coosa, and Chilton counties. The report is accompanied by maps and illustrated by excellent half tones.

The economic factor has a very prominent place throughout the report, and will doubtless render it very helpful in developing the important resources of the region. C.

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*First Report of the Geological Commission of the Colony of the Cape of Good Hope.* Capetown, 1896.

The Geological Survey of the Colony of the Cape of Good Hope was recently organized by the appointment of Professor Corstorphine as geologist, and Arthur W. Rogers and Ernst H. L. Schwarz as assistant geologists. Considering the limitations of time, of means, and of personnel, this first report indicates an active prosecution of the work entrusted to the commission. The report in hand contains brief contributions on the following subjects: "Report on the Laingsburg Coal," by Professor Corstorphine; "Summary of the Work done in the Southwestern Districts," by Rogers; "Survey of the Beaufort West District," by Schwarz; "Summary of the Work done in the Tulbagh Area and Worcester District," by Schwarz; "Report of the Subcommittee on Deep Artesian Well Borings," by Stewart, Corstorphine, and Saunders; "Report of a Preliminary Geological Survey of

the Oudtshoorn and Prince Albert Districts made with a view to the Selection of a Site for a deep Borehole for Artesian Waters," by Corstorphine, and "The Cango Cave," by the same. Geologists will wish this new survey in a far-off land all possible success. C.

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*North Carolina and Its Resources.* Issued by the State Board of Agriculture, Raleigh, 1896.

This is a general work intended to set forth the natural and cultural interests of the state. The subjects of geological interest are the topographic sketches illustrated by half tones, the climatic statistics, a geological map, a list of native minerals, a sketch of the gold, silver, copper, iron, corundum, mica, talc, monazite, marl, phosphate, coal, graphite, kaolin, and clay industries, and of the gems and gem stones of the state. The building stones and road material are also briefly treated. The work is well illustrated with excellent half tones, and is a very creditable book. C.

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*Bulletin of the Minnesota Academy of Natural Sciences*, Vol. IV, No. 1, Part I. *Proceedings and Accompanying Papers 1892 to 1894.* By C. W. HALL, Editor. Minneapolis, 1896.

The papers of geological interest are: "Notes on the Alpine Characteristics of the Minnesota Flora of the Coteau des Prairies," by E. P. Sheldon; "The St. Peter's Sandstone," embracing descriptions of its fauna, including fourteen genera and twenty-eight species, and a discussion of its origin and correlation, by F. W. Sardeson; and "The Fauna of the Magnesian Series with Descriptions of its Fossils," by F. W. Sardeson. The large additions to the fauna of the Magnesian and St. Peter's horizons gives special value to these two papers. C.

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*Proceedings of the Iowa Academy of Sciences for 1896.* Vol. IV, Des Moines, 1897.

The volume contains a portrait of the late Charles Wachsmuth, accompanied by a memorial by Dr. Charles R. Keyes. The papers of geological interest are "The State Quarry Limestone," by Samuel Calvin; "Stages of the Des Moines, or Chief Coal-Bearing Series of

Kansas and Southwest Missouri and their Equivalents in Iowa," by Charles R. Keyes; "The Vertical Range of Fossils at Louisiana," embracing an extended table, by Charles R. Keyes and R. R. Rowley; "Natural Gas in the Drift of Iowa," by A. G. Leonard; "The Results of Recent Geological Work in Madison County," by J. L. Tilton; "The Drift Section at Oelwein," by Grant E. Finch; "Evidence of a Sub-Aftonian Till Sheet in Northeastern Iowa," illustrated by a section and three full page half tones, by S. W. Beyer; "A Pre-Kansan Peat Bed," by T. H. MacBride; "A Summary of the Discussion of the Preceding Papers on the Oelwein Section," by Professor S. Calvin; and "Additional Observations on Surface Deposits in Iowa," by B. Shimek. The remaining papers are chiefly biological.

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*Proceedings of the Davenport Academy of Natural Sciences*, Vol. VI, 1889 to 1897. Davenport, 1897.

In this volume of 400 pages the archæological contributions very notably predominate. Some of these, however, possess geological interest from their connection with recent deposits. The dignity of the volume and of the society is lowered by an endorsement of the ridiculous claims of Captain Glazier, which are unworthy of serious consideration.

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*Stone Implements of the Potomac-Chesapeake Tidewater Province.* By WILLIAM H. HOLMES. From *Fifteenth Annual Report of the Bureau of Ethnology*. J. W. POWELL, Director. Washington, D. C., 1897.

This paper, though primarily archæological, possesses much geological interest because of its bearing upon anthropic geology. It consists of an elaborate discussion of the manufacturing of flaked stone implements and of the ancient quarry workshops of the District of Columbia, in which this manufacture was extensively carried on. The geological relations of these quarries and of the terranes in which they occur are accurately and fully set forth by sections, photographs, and sketches of the clearest possible type. The various stages of manufacture are fully elucidated by drawings and photographs, so that every feature of the process is most completely and convincingly elucidated. The conclusions reached by Professor Holmes are already

familiar to the readers of this magazine. The results of his prolonged investigations are here brought together, summed up and illustrated with a beauty and force which make the paper a monumental contribution to archæology and anthropic geology. C.

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*Glacial Observations in the Umanak District, Greenland.* By PROFESSOR GEORGE H. BARTON. *Report B of the Scientific Work of the Boston Party on the Sixth Peary Expedition to Greenland.*

The paper embraces the observations made by Professor Barton on the border of the inland ice in the vicinity of Umanak fiord and upon the large Karajak, Itivdliarsuk and several small valley glaciers. Mr. Barton found the border of the ice usually nearly vertical to the height of ten to forty feet. The surface in the vicinity of the margin was covered with dust holes ranging in diameter from a fraction of an inch up to at least three feet, with an average depth of about two feet. Except the dust found in these holes no detritus occurs on the surface of the inland ice. The largest surface stream found flowed in a channel having a width of twenty feet with a depth of fifteen feet to the surface of the water which was about five feet in depth. At the point observed this river was flowing directly toward the interior with a velocity of three or four miles an hour. The average gradient of the surface measured on the Karajak glacier was found to be 1 in 52. Professor Barton observed that the overhanging marginal faces were in many cases apparently due to a shearing motion of the upper layers over the lower. "This was indicated quite strongly in one instance, where a layer projecting slightly beyond the ones above had caught a little detritus as it rolled down. This same ledge continued from the slightly inclined face along a portion of the overhanging face, and here still the detritus remained which had been caught in its descent before the shearing motion had changed this part of the face to an overhanging one. A cavern presented a chance for a study of the material forming the layer upon which the detritus had lodged, and also for several feet above, showing them to be free from detritus and consequently that the detritus could only have come from the upper surface and caught upon the shelf, while the face was inclined, and that its present overhanging form was due to the shearing motion in the upper portion of the ice"—a very important observation.

Professor Barton gives interesting illustrations of the hold of the

ice upon bowlders, and of its methods of behavior in passing over projecting knobs of rock. He also gives an instructive diagram of the method of discharge of the ice foot where it protrudes into the water. Professor Barton believes that the ice "once extended over all this portion of Greenland, passing out beyond the farthest limits of the present coast line into the open waters of Baffin's Bay." He is not altogether fortunate in his suggestions with reference to Dalrymple Rock, a figure of which he introduces for comparison, with the suggestion that it "presents a marked stoss and lee side, apparently in their appropriate positions as related to the mainland topography seen in the distance." The apparent stoss side faces Baffin's Bay and not the inland ice. There is a radical difference between Dalrymple Rock and the peaks of Ikerasak and of Umanak Island, with which it is put in comparison, in the fact that the pedestals of the two latter are distinctly glaciated, showing that they have been typical nunataks, while the base of Dalrymple Rock shows no signs of glaciation and belongs in an entirely different category.

The paper is admirably illustrated with half tone photographs.

T. C. C.

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*Seventeenth Annual Report of the United States Geological Survey* Part I, Director's Report and other papers; Part II, Economic Geology and Hydrography; Part III, Mineral Resources of the United States. CHARLES D. WALCOTT, Director, Washington, D. C., 1896.

This volumnious report embracing three thousand pages of matter which has just come to hand can only be briefly noticed here. It is hoped that special reviews of its important papers may be given hereafter. The report opens with the usual statement of the operations of the survey by the Director. It includes the work done in the years 1895–6 by the nearly forty parties in geology and palæontology, by the divisions of chemistry and hydrography, by the statisticians, and by the topographic and publication branches. This is followed in Part I by papers on "The Magnetic Declination in the United States," by Henry Gannett; "A Geological Reconnaissance in Northwestern Oregon," by J. S. Diller; "Further Contributions to the Geology of the Sierra Nevada," by H.W. Turner; "A Report on the Coal and Lignite of Alaska," by W. H. Dall; "The Uintaite (Gilsonite) Deposits of Utah,"

by G. H. Eldridge; "The Glacial Brick Clays of Rhode Island and Southeastern Massachusetts," by N. S. Shaler, J. B. Woodworth and C. F. Marbut; and "The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast," by T. W. Stanton.

Part II embraces "The Gold-Quartz Veins of Nevada City and Grass Valley, California," by Waldemar Lindgren; "The Geology of Silver Cliff and the Rosita Hills, Colorado," by Whitman Cross; "The Mines of Custer County, Colorado," by S. F. Emmons; "A Geological Section Along the New and Kanawha Rivers in West Virginia," by M. R. Campbell and W. C. Mendenhall; "The Tennessee Phosphates," by C. W. Hayes; "The Underground Water in the Arkansas Valley in Eastern Colorado," by G. K. Gilbert; "A Preliminary Report on the Artesian Waters of a Portion of the Dakotas," by N. H. Darton; and "The Water Resources of Illinois," by Frank Leverett, accompanied by an account of the "Palæozoic Rocks Explored by Deep Borings at Rock Island, Ill.," by J. A. Udden.

Part III embraces the "Report on the Mineral Resources of the United States for 1895," by Dr. David T. Day and associates. This includes reports on The Iron Ores, by John Birkinbine; on The Present Condition of the Iron and Steel Industries of the United States, by James M. Swank; on Copper, Lead and Zinc, by Charles Kirchoff; on Chromic Iron, by William Glenn; on Antimony, Coal, Asphaltum, Soapstone, Abrasive Materials, Sulphur and Pyrites, Gypsum, Salt, Asbestos. Mineral Paints and Barytes, by Edward W. Parker; on Manganese, Coke, Petroleum and Natural Gas, by Joseph D. Weeks; on Stone, by William C. Day; on Clay, by Jefferson Middleton; on Pottery, by Heinrich Reis; on Portland Cement, by Spencer B. Newberry; on American Rock Cement, by Uriah Cummings; on Precious Stones, by George F. Kunz; on Mineral Waters, by Alfred C. Peale; and on Gold, Quicksilver, Tin, Aluminium, Nickel, Cobalt, Platinum, Phosphate Rock, Fluorspar, Chryolite, Mica and Graphite, by the chief of the division.

Altogether the list of papers is one of unusual range and importance. C.